Fish attractors in impoundment fisheries

A best practice guideline

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The Department of Agriculture and Fisheries proudly acknowledges all First Nations peoples (Aboriginal peoples and Torres Strait Islanders) and the Traditional Owners and Custodians of the country on which we live and work. We acknowledge their continuing connection to land, waters and culture and commit to ongoing reconciliation. We pay our respect to their Elders past, present and emerging.

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Preface

This document has been compiled from various sources and, to the authors' knowledge, represents the best advice currently available regarding the use of fish attracting structures to improve recreational angling in Australian impoundments. Although the principles outlined in this document may apply to impoundments across Australia, most examples and references relate specifically to Queensland and the USA, where most of the research has been undertaken to date. Research on the use of fish attractors in impoundments is in its infancy in Australia, and therefore many examples and recommendations are based on research from the USA, where the field is much more advanced.

Although the information in this document is provided in good faith, it should be used as a guide only. It is not possible to make absolute statements or foolproof recommendations regarding the use of fish attractor strategies that will apply equally to all impoundment scenarios. We have attempted to point out the key factors that can lead to differing success rates among fish attractor programs, particularly in terms of the project objectives, structures used, and the fish species being targeted. However, given the almost infinite number of possible combinations and permutations of these factors, there can be no guarantee that strict adherence to the recommendations given in this document will always result in the best possible outcome.

We are, however, confident that a thoroughly planned fish attractor program that takes into account the principles and issues outlined in this document will stand a much greater chance of success than one which is hastily conceived without due regard for potential influencing factors.

Introduction

Current approach impoundment fisheries management

The management of impoundment fisheries in Australia currently relies primarily on stocking and harvest control through size and bag limits (Hutchison *et al.* 2006, Norris 2016). These approaches aim to ensure sufficient fish stocks occur in a waterbody through artificial recruitment and management of angler take. However, only limited effort has been put into managing impoundment fisheries through fish habitat enhancement, and the potential benefits of this approach have yet to be realised in Australia.

Aquatic habitat is important to fish

A wide range of variables impact the success of an impoundment fishery, but a key limiting factor is often the condition and availability of fish habitat (Miranda 2017, McCartney *et al.* 2018). The availability of suitable habitat is an essential requirement for fish to accomplish daily and seasonal survival tasks such as foraging, sheltering and reproducing (Jackson *et al.* 2001). When key fish habitat is absent, in poor condition or declines in quantity or quality, the fishing in the impoundment often also declines. Quality fish habitat is therefore vital to support strong fish communities and fishing opportunities.

Most impoundments have been built and operated for flood mitigation, town water supply, irrigation or to generate hydroelectric power, but often with little regard towards fisheries. In many cases timber habitat is cleared prior to the initial flooding of a reservoir, leaving limited structural complexity. Another major challenge facing impoundment fisheries is the decline in fish habitat due to the natural effects of impoundment ageing. Over time the remnant woody habitat degrades but is not replaced. Ageing occurs in impoundments at a much greater rate than natural lakes, and this is even further accelerated where water storage levels fluctuate significantly (Miranda 2017).

Use of habitat enhancement as a management tool

Improving the quality and quantity of fish habitat in impoundments has the potential to enhance survival, growth rates and the carrying capacity of stocked fish. The addition of habitat has also long been an established technique used by fishermen and managers to concentrate fish and increase catch rates (Pardue and Nielsen 1979, Wege and Anderson 1979, Johnson *et al.* 1988, Bolding *et al.* 2004, Miranda 2017). Fish are rarely randomly distributed around an impoundment. Many iconic angling species, such as barramundi and Murray cod, show a strong affinity towards structurally complex habitat (Allen *et al*. 2003). Strategically improving the quality and quantity of structural habitat in an impoundment can create aggregation points for prey species and ambush locations for predators. This has the potential to create new fishing hotspots and improve fishing in and around these sites. Improving structural fish habitat could also help sustain or even increase an impoundment's carrying capacity, especially for highly territorial species such as Murray cod.

Fish habitat enhancement

Aquatic habitat enhancement has been practiced around the world for thousands of years by fishers. They realised that fish are captured more readily near structures such as rocks, reefs, fallen trees and floating debris, than in areas devoid of such structures. Habitat enhancement to improve fisheries is still commonly practised today, particularly in the marine environment. Enhancement and restoration work has also been undertaken in freshwater systems, but this has mostly focussed on habitat in rivers and streams. Fisheries habitat enhancement has less commonly been undertaken in impoundments and lakes, but this trend is changing.

Reservoir habitat enhancement has been effective in the USA

There is a convincing body of evidence from the USA that habitat enhancement in impoundments has improved their fisheries (Norris 2016, Miranda 2017). Reservoir habitat enhancement has been occurring for more than 80 years in the USA to counter declining fisheries from reservoir degradation or make it easier for anglers to find and catch fish. This approach is utilised in some form by more than 80% of USA state fisheries agencies (Tugend *et al.* 2002). The fishing in many USA reservoirs has been substantially improved, or even completely revitalised through the strategic use of fish habitat enhancement techniques. This has led to significant improvements in the quality of fishing for local anglers and increased the number of tourists visiting or utilising these impoundments. The enhancements have generated significant flow on benefits to the local communities (Norris 2016).

Different strategies have been used in different states and across a wide range of scenarios. Some USA states have focused on installing habitat for fish attraction, whilst others have aimed to increase impoundment productivity (Norris 2016). Both approaches have the potential for large-scale benefits to anglers and can be undertaken independently or in conjunction with each other. Improving impoundment productivity has typically been a very large and expensive process and often included improvement of spawning habitat for multiple species. Using habitat to attract fish to specific areas can be less expensive and the results may become apparent more quickly. However, care needs to be taken that the number of fish kept by anglers does not become greater than the fish population can tolerate.

Why use fish attracting structures (FAS) in Australian impoundments

Many impoundments in Australia are developed as put-grow-take fisheries. Most species targeted by anglers rely on stocking to support their populations, because they do not breed successfully in impoundments. Installing habitat to improve spawning would therefore be of limited benefit for most species. The most cost-effective use of habitat enhancement in Australian impoundments would be to install structures to attract fish to improve angling, and this is the focus of these guidelines.

Many fish stocking groups are looking for ways to enhance their impoundment fisheries through means other than stocking fish. During periods of low water, fish stocking in some dams is greatly reduced or even halted. Habitat enhancement is an alternative strategy for groups wishing to improve the quality of their impoundment fishery during such times.

Locating fish in an impoundment is one of the keys to productive fishing. Inexperienced anglers, or those new to an area, can have difficulty locating good fishing spots. The lack of structural habitat in many impoundments also means boat anglers often need to cover extensive distances to locate fish. Providing structural habitat through the installation of fish attractors and advertising their positions can help such anglers more easily locate and catch fish, and thus have a better fishing experience. Additionally, some dams have only limited access for shore anglers, but these areas do not always correspond with good quality habitat where fish are likely to be found. Installing fish attractors at shore access sites could help lure more fish into those areas and make the fishing more productive.

Sometimes the best fish habitat occurs around the dam walls and other infrastructure, and anglers are generally forbidden to fish here due to safety concerns and protection of assets. Installing fish attractors may help entice fish from these closed regions into areas where angling is allowed.

The need for guidelines on the use of fish attractors in impoundments

The use of fish attractors in impoundments has great potential to improve recreational fishing in Australian impoundments, but this approach has rarely been undertaken or evaluated. Many fish stocking groups and fisheries agencies are looking to use habitat to enhance their impoundment fisheries. Guidelines on the use of fish attractors are needed, to ensure this occurs safely and effectively. Fisheries managers see development of such best-practice guidelines as critical before they can support widespread use of this approach in impoundments.

Waterway operators have also expressed some reservations on the safety of installing fish attracting structures. If installed incorrectly, such structures have the potential to shift during flow events and potentially damage important infrastructure. Structures placed in inappropriate locations could also pose a strike risk for boaters, water-skiers and other waterway users. The use of inappropriate construction materials or illegal dumping could pose a potential risk to dam water quality and increase the cost of water treatment. Clear guidelines outlining suitable fish attractor designs, materials and deployment locations will help minimise any such risks and have been requested by several key impoundment operators before fish attractors will be allowed to be widely used.

A potential concern raised by some fisheries managers has been that fish attractors may increase angler harvest to unsustainable levels. In impoundments which rely on natural recruitment to support the fishery this must be taken into consideration when contemplating a fish attractor project. However, most Australian impoundments rely on stocking to support their fisheries and are designed to be put-grow-take systems. Recruitment is controlled by the number of fingerlings stocked and many anglers also practice catch and release fishing. The risk of overharvest of impoundment fish populations through increased angler catch is therefore generally low and manageable.

Fish attractors also have potential to help increase survival of fingerlings stocked into impoundments where structural habitat is limited. Predation is the largest source of mortality in stocked fingerlings, and the addition of complex habitat structure can provide refuges to evade predation. Significant increases in the survival of both stocked fingerlings and wild recruits has been recorded in the USA after the introduction of complex habitat. Juvenile habitat requirements can be readily incorporated into fish attracting projects, but more research is required to demonstrate how this can best be achieved for Australian native fish.

A large variety of structures have been used to attract fish in impoundments, but not all designs and materials have been optimal or would be suitable for use in Australia. Information on fish attractor design, construction, placement, durability and effectiveness needs to be consolidated so the technique can be widely implemented in a cost-effective manner. Recent trials in Australia, coupled with information from overseas studies provide a good foundation for the use of fish attractors in Australian impoundments.

Types of fish attractors

Careful consideration needs to be given to the types of fish attractor that will be most effective in addressing the project objectives and the target species. The principal role of most installed habitat structure is to aggregate fish for anglers to increase their catch. The consensus is that in the absence of other habitat, all fish habitat structures will attract fish, but the relative effectiveness varies between structure types and fish species. Despite more than 50 years of research, identification of the most effective fish attractor materials and structure designs for aggregating sportfish still continues in the USA (Miranda 2017). Knowledge is much more limited with regards to the response of Australian fish species to fish attractors, but many of the overseas learnings can be refined and applied.

Fish attractors can work by directly providing ambush habitat for the fish species targeted by anglers, or they can also provide suitable habitat for food and prey species targeted by these species. Over time, a localised ecosystem develops around fish attractors as algae and other periphyton grows. This in turn attracts shrimp and smaller fish species, which then attract the larger sportfish.

With so many types of fish attractors available, we have compiled a list of commonly used designs and general information for each structure to provide a starting point for fish attraction projects. As more projects are completed and research progresses, the list will be updated to include new structures, information, and recommendations.

Materials used to construct fish attractors

Historically fish attractors were largely constructed from materials that were convenient, affordable and readily available. Common habitat structure materials include concrete, rock, brush, limestone, steel, plastics, ceramics, wood, and PVC pipes. As knowledge in the field has grown, more specialist fish attractors have been created to service the specific needs of some species. Fish attractors used in impoundments can be classified into three general types: (1) tree, brush, and timber structures; (2) structures constructed from stone materials; and (3) structures constructed from synthetic materials such as plastics. The debate on whether fish prefer structures made from natural (i.e. timber, woody debris, rock piles, etc.) or synthetic (i.e. plastic, steel, concrete etc.) materials is ongoing, but both types of habitat structures have been successful at attracting fish.

The type of materials used to construct fish habitat can also determine where they are suitable for use. For example, managers in reservoirs with hydro-electric power stations often do not allow installation of brush structures because of fears debris may block up the power station turbine intakes (Norris 2016). Similarly, in some reservoirs which are primary sources of potable water for towns, synthetic structures are only allowed to be used because of concerns over the impacts of brush and timber degradation on water quality. Decomposing organic material can react with the chlorination process for drinking water, creating trihalomethanes (Feger and Spier 2010). Discussions with the waterway operator will help clarify any constraints for a particular impoundment.

Concerns have also been raised over the potential accumulation of pollutants (e.g., organochlorine pesticides, polychlorinated biphenyls and polycyclic aromatic hydrocarbons) absorbed from the surrounding waters into some types of plastics (Zicchardi *et al.* 2016). If the plastics break down over time due to exposure above water, they can become hazardous to fish. Polyethylene is reported to accumulate more contaminants than polypropylene or PVC (Rochman *et al.* 2013), suggesting the latter two materials should be preferred for fish attractor construction. Much of the research into the risks associated with plastic breakdown and pollutant accumulation has been conducted in marine systems. There is limited information available on how the use of synthetic materials may impact freshwater ecosystems. The likely scale of their impacts on fish although unknown, is likely to be very low. PVC pipes are widely used to deliver potable water to households and appear to be a safe option.

Durability

The durability of different fish attractors can vary greatly between construction materials and designs. Durability determines the functional lifespan of fish attractors and is a critical factor in evaluating the overall cost-effectiveness of different designs. Brush bundles, evergreens and tree tops have been found to degrade within 3-7 years (depending upon the timber) to a point where they require supplementation or replacement to remain functional. In cooler water impoundments, degradation of brush materials is slower and their long-term value for use as fish attractors is greater (Bolding *et al.* 2004). Fish attractors constructed from large timber posts, stumps and trees cost more initially, but last longer (20-50 years) particularly if they remain fully submerged. In comparison, synthetic materials are often much better at attracting and holding fish over a long period of time because they require less maintenance or replenishment. They therefore can provide long-term value if the designs effectively attract fish. Fish attractors made with concrete and rock are extremely durable and hence also provide long-term value.

Interstitial space

The size and number of interstitial spaces (= gaps and crevices in a structure) provided by a fish attractor is important in determining which type should be installed. Interstitial space size influences the species and size classes attracted to a particular structure.

Smaller interstitial spacing often attracts a greater size range of fish, but more open structures have been found to be better at attracting the larger sportfish. However, this varies between fish species. Fine interstitial spacing is possible with both synthetic and natural materials, but using fine spacing can make angling more difficult. If anglers lose more fishing tackle, they may be less likely to fish in those areas.

Fish often need to compromise between optimal feeding strategies and predator avoidance. Very complex substrates with fine interstitial spacing are preferentially selected by small fish, as it helps them to evade predators. Conversely, larger fish prefer habitat structures with medium to large gaps, providing them with a better balance between hiding from prey and having sufficient opportunity to ambush and capture their food successfully. This suggests that some habitats may support fewer, larger predatory fish, while others may support more numerous, but smaller individuals.

Fish attractor designs with smaller interior spaces and greater structural complexity may be more suitable to improve habitat for fingerlings and prey populations.

Fish attractors need to suite the target species

One key consideration in fish attractor projects is determining which type of structures will be most effective at addressing the management objectives for the target species. Fish attractors can target a variety of fish species at multiple life stages. Fish that prefer shady under-hangs will respond best to fish attractors with horizontal components that create shade. By comparison, open water or pelagic species are likely to respond best to more open fish attractors that create ambush opportunities but are not too constricted so as to inhibit feeding success. Some species targeted by anglers occupy the upper parts of the water column (e.g. saratoga), whilst others prefer to live in a broad swathe of the water column (e.g. Australian bass) or in proximity of habitat on the bottom (e.g. silver perch).

Make fish attractors easy for anglers to fish

The materials and design have a large impact on how often anglers get their fishing tackle snagged on structures and this can influence the angling methods used when targeting fish attractors. Where possible, selecting and constructing relatively snag-less structures will enable the broadest range of fishing techniques to be used. Highly complex structures with many small interstitial spaces are the most likely to snag fishing gear. For example, brush bundles are highly vulnerable to gear entanglement. Specific techniques or lure types may need to be employed by anglers to fish near these structures, increasing the probability of hooking fish whilst decreasing the chance of entanglement. This may lead to avoidance of fishing around these areas by some anglers. More open designs, or the use of construction materials with dimensions greater than typical hook gape widths, can greatly reduce hooks snagging on structures. Similarly, hooks are less likely to get caught in materials with round profiles. The hardness of the materials used in fish attractor construction also plays a role in the frequency of snagging. Harder materials like PVC are difficult for hooks to embed into and thus more snag resistant. Softer materials, like the polyethylene used to create the limbs in the spiders, may be more readily penetrated by hooks. However, snag resistance in spiders is accomplished by limb flexibility, and construction with pipe of greater diameter than the typical hook gape. Similarly, the corrugated drainpipe used in the construction of Georgia cubes is made of polyethylene but relies upon the large diameter to prevent hook penetration and snagging.

Modular habitats are easier to construct and deploy

Large fish attractors can look impressive and are effective, but may be substantially more difficult and expensive to construct and deploy. Such structures are often most cost effectively used when they can be installed during low water levels. A wide range of fish attractors exist that are modular, relatively light-weight, easy to construct, easy to deploy, and relatively cheap. These traits make such fish attractors suitable for construction and installation by community groups, such as fishing and stocking clubs. Larger habitat structures can be created by clustering multiple modular structures adjacent to or on top of each other. Light weight structures should not be deployed in rivers or areas subject to strong currents and are best deployed in the sheltered bays of impoundments.

Fish attractors made from timber and brush

Woody structures have proven very effective at attracting fish and can be beneficial to other aquatic organisms. These structure types mimic the natural habitat of many species of fish. Fish attractors made from timber and brush remain some of the most commonly used structures because the materials are readily available and typically free or cheap to source. Structures made from branches and tree tops are light and easy to deploy so large numbers can be installed relatively quickly and cheaply. Larger timber structures such as whole trees, fish hotels and root balls are heavier and more difficult and costly to transport and install. The type of timber or brush fish attractors to use will depend upon the behaviour of the target fish species, use of the waterway, project budget, waterway operator conditions and material availability. Some examples of effective fish attractors constructed with brush or timber are given below, but these are not exhaustive and other designs may be suitable.

Brush bundles

Branch bundles and recycled Christmas trees are one of the most basic and commonly used fish attractors. Bundles of brush or branches are tied together by wire or rope and concrete blocks, or cement bricks are attached to sink the structures and anchor them in place on the bottom. Freshly cut brush requires less weight to sink and is the preferred material. The size of the fish attractors can be modified by altering the number of branches in the bundle and by stacking bundles on top of each other to increase height and substrate coverage.

Palm fronds have generally been found to make poor brush bundles. The fronds lack the interstitial spaces and complexity observed in other plants. They quickly break down leaving only the main stems and are not recommended.

Brush bundles initially provide dense cover with fine interstitial spaces that are favoured by small fish and juveniles of larger species. In impoundments with limited cover for small fish, installation of brush bundles has the potential to improve survival rates of stocked fingerlings. However, as the brush ages, finer limbs are lost relatively quickly, and only thicker branch sections remain. This makes the structures less attractive to small fish but the remnant, more open branches are likely to be more attractive to larger fish. The small interstitial spaces result in high potential for fish gear entanglement. The durability of this type of fish attractor is low and replenishment needs to be conducted regularly for the bundles to remain attractive to fish. Hardwood brush lasts longer than softwood or evergreen brush. As the bundles degrade there is potential for broken debris to be released, but this is typically small and unlikely to cause many issues unless used in hydro-power reservoirs. Brush bundles may also stimulate local productivity by promoting periphyton growth and supporting many aquatic species.

Pros:	*Cheap, easy to deploy, attract a wide range of fish sizes*
Cons:	*Degrade quickly, high fishing gear entanglement, potential to release debris, require regular replenishment*
Depth:	*All depths, but mostly used in shallower water due to limited vertical profile*
Durability:	*Short term 3-7 years*

Brush bundles ready to be deployed. Right image: Missouri Department of Conservation

Under water images illustrating the complex structure brush bundles create once deployed.

Crappie condos

Named after a North American fish regularly targeted by anglers, “Crappie condos” are a vertical version of brush bundles. Bundles of fine branches are placed at angles into cement in a bucket, creating a vertical bush-like structure. Lighter timbers are most suitable, but bamboo is the best due to its buoyancy and durability. The structures are easily deployed from boats or barges and tend to right themselves when dropped due to the buoyancy of the limbs and heavy bucket end. Crappie condos are cheap to construct and deploy, and can provide good vertical structure.

Crappie condos. Image: Texas Parks and Wildlife Division

Pros:	*Cheap, easy to deploy, attract a wide range of fish sizes*
Cons:	*Degrade quickly, moderate fishing gear entanglement, require regular replacement*
Depth:	*Medium to deep*
Durability:	*Short term 3-9 years depending on timber used*

Tree tops

Tree tops or crowns can provide great habitat for fish and mimic naturally fallen timber. Tree tops are generally more voluminous than brush bundles and provide greater vertical profile in the water column. Tree tops are typically anchored with concrete blocks or bricks. Freshly cut pieces are preferred because they retain more moisture and thus require less weight to initially sink. If selective harvesting along the shoreline is possible, tree tops can be quite quickly and cheaply installed. However, local legislation generally restricts the harvest of trees and tree tops, and it may be preferable to source them from private property. Regulations vary by state and local government area and permission must be obtained for any cutting. Alternative potential sources include from main roads departments, local council prunings, post storm damage debris, and trees cleared by farmers. These groups are likely to already have a permit to fell or clear trees for another purpose, and thus the tops of felled trees can be repurposed rather than mulched or burnt. Where tops are specifically cut along the shoreline, it should occur as close as possible to the destination site and towed out to the site by boat for placement. Appropriate anchor weights are attached, and the structure is sunk. The amount of weight needed to sink and hold the tree top in position depends upon the structure size, but typically 5 – 10 x 20 kg concrete anchors are used. More weight is needed where the structures experience any water flow. The small interstitial spaces result in high potential for fish gear entanglement. The durability of tree tops is low, and only slightly better than brush bundles because more thick branches are typically present. Regular replenishment is required. As tree tops degrade there is potential for some debris to break off and drift. Like brush bundles, smaller fish tend to congregate on tree tops that provide dense cover, whereas larger fish congregate around tree tops that provide less dense cover.

A fresh tree top being towed out for sinking.

Pros: *Cheap, easy to deploy, attract a wide range of fish sizes*

Cons: *Degrade quickly, high fishing gear entanglement, potential to release debris, require regular replenishment, potential regulatory issues with sourcing the timber*

Depth: *Medium to deep*

Durability: *Short term 4-9 years*

Whole trees

Installation of whole trees as fish attractors can be highly effective and their value has been widely proven in river systems. The use of whole trees to attract fish is a longer-term option, but the difficulty and cost of installation can also increase. Like brush bundles and tree tops, the finer branches and leaves will degrade relatively quickly. However, the larger limbs and trunks will remain intact for longer, especially in hardwood species. As interstitial space is lost to decay, the fish assemblage occupying the tree probably shifts toward larger individuals.

Where water levels are relatively stable, the shoreline drops away at least moderately steeply, and selective shoreline felling is permitted, cut-and-cable or hinge-cutting can be very quick and cost-effective techniques to install whole trees. Suitable trees are identified and felled into the water with the cut leaving approximately 1 m of stump height. For cut-and-cable, a hole is drilled through both the fallen trunk end and the remnant stump. These are connected to each other using suitable wire to ensure the felled tree cannot move. For hinge-cutting, trees are cut near their base just deep enough so that the tree can be pushed into the water but remain attached to the trunk. Hinge-cut trees cut about two-thirds of the way through the trunk may continue to live for months to several years. Hinge-cutting works best for younger trees because they are more flexible and less likely to break. The advantages of these techniques include low cost, speed of operation and leaving the root mass to stabilise the shoreline.

Unfortunately, suitable scenarios for cut-and-cable or hinge-cutting are not common and typically whole trees need to be installed by a truck or barge. Transporting and installing trees requires heavy machinery and therefore can be expensive. Anchoring large trees requires significant weight to ensure they do move during flow events. Pinning or multiple concrete blocks connected by heavy duty wire cable are commonly used to anchor trees in place. Retaining the root ball on trees provides great additional structural complexity for fish and the protruding roots help anchor the tree in place.

Pros:	*Large, complex habitat, attract a wide range of fish sizes, relatively durable*
Cons:	*Difficult and expensive to install (unless cut-and-cable), high fishing gear entanglement, potential to release debris, difficulty in sourcing whole trees, legal restrictions regarding felling of trees.*
Depth:	*Medium to deep*
Durability:	*Medium term 8-25 years*


A cut (left) and cabled (right) tree.

Tree stumps

Fish attractors have been created using just the stumps of trees. Stumps are a frequent by-product of land clearing or tree removal (e.g. from roadworks) and can provide complex structural habitat attractive to fish. Tree stumps are typically very weighty and require heavy machinery to transport and install them. Although they are often available at no charge, the installation costs can make them expensive to use as fish attractors. Specialised barges may be needed for deployment unless installation can occur during low water levels. The protruding roots provide the structural complexity for fish and anchor the structures in place. The vertical profile in the water column is limited. The weight of the stump means no anchor weights are required to prevent them shifting in impoundments. Tree stumps are very durable, require no maintenance, and should provide medium to long term benefits. Tree stumps are reported to be less effective than whole trees at attracting some fish species due to the lower amount of branching and limited vertical profile in the water column. They can be effective for territorial species, such as Murray cod, which can exclude other fish from their area. Tree stumps are typically scattered across an area, but can also be piled to create larger structures. Deployment is generally much easier and more precise using a truck and loader when water levels are low.

Pros:	*Provide complex habitat, very durable, cheap to source, no additional ballast required for anchoring*
Cons:	*Difficult and expensive to install, high fishing gear entanglement, potential to release debris*
Depth:	*Medium to deep*
Durability:	*Medium to long term 15-25 years*

Tree stumps deployed during low water and being deployed off a barge. Images: Missouri Department of Conservation

Porcupine cribs

Porcupine cribs are small, layered timber pyramids developed by the Pennsylvania Fish and Boat Commission to provide long-lasting, complex deep-water fish habitat. Originally designed as habitat refuges for bottom fish, they can also be effective as fish attractors. The design consists of approximately fifty 1.2 m long pieces of 50 mm x 50 mm rough-cut timber arranged in rows of two. Each layer is stacked at 90 degrees to the previous layer with the overlapping joins tapering inwards to form a pyramid. The pieces of timber are joined with galvanised nails where they cross over, and UV stabilised pallet strapping is placed around the completed structure to ensure the joints do not separate. Concrete blocks are attached to the lower section of the cribs to sink them and anchor them in place. This design is highly stable because the centre of gravity is located over the middle of the structure, but the vertical profile is limited to approximately 1 m. The protruding ends of the timber pieces offer overhangs for fish to use as shelter or ambush points, and the design offers reasonable resistance to fishing gear entanglement. Purchasing timber for cribs can be expensive and construction can take some time unless a nail gun is used. Pre-drilling nailing points can help limit splitting of the timber pieces. Structures can be built in place during periods of low water levels or deployed from a boat. A rope looped at the top may be required during deployment from boats to guide cribs into position and ensure they sink vertically. Porcupine cribs are typically placed in medium to deep sites in rows or clusters of 10 to 20 structures per site. The cribs are very durable when they remain submerged, especially if hardwood timbers are used in construction. Note that hardwood cribs can be heavy and require careful consideration of how they get deployed.

Pros:	*Durable complex habitat, suitable for a range of fish sizes, unlikely to shift or release debris, reasonable resistance to fishing gear entanglement*
Cons:	*Relatively expensive to construct, may require larger vessels to deploy, limited vertical profile*
Depth:	*Medium to deep*
Durability:	*Medium to long term 15-25 years*

Porcupine cribs deployed on ice and ready for deployment off a barge. Left image: Pennsylvania Fish and Game

Fish hotels

Fish hotels are a larger version of the porcupine cribs and have been previously used to enhance fish habitat in rivers. They are heavy structures and normally constructed from recycled timber railway sleepers or cut sections of tree branches/trunks. Fish hotels are very stable and will not shift if constructed properly. The timber beams are approximately 2.4 m long and stacked in alternate directions to create a structure height of 1.5-2.0 m. The best design forms a pyramid pattern with the overlaps similar to porcupine cribs. The protruding sections of the logs provide great resting or ambush opportunities, and the pyramid shape creates more horizontal cover and shade. Alternately, a squarer design like a log-cabin with a larger opening in the centre can be used. The disadvantage of this design is that it provides less overlapping complexity, and the large space can be dominated by a single large fish in territorial species. Both designs also have no small interstitial spaces and are considered open structure designs. The joints are secured by large threaded rod and a safety line of chain or wire is also looped around the structure. Concrete railway sleepers are good for providing the ballast needed to anchor the fish hotels in place. Due to the weight of fish hotels, specialised heavy equipment is required for transport and deployment. Fish hotels can be built on site during low water levels. Construction costs are high, but the finished fish attractors are extremely durable and should last a very long time. Fish hotels have a good resistance to the entanglement of fishing gear, but the growth of periphyton on the structures may cause some snagging. Fish hotels are best suited to medium to deep water depths.


Fish hotel

Pros:	*Very durable complex habitat, will not shift or release debris, good resistance to fishing gear entanglement, decent vertical profile, suitable for areas with current*
Cons:	*Expensive to construct, require heavy machinery to transport and deploy, limited fine interstitial spacing*
Depth:	*Medium to deep*
Durability:	*Long term 25-75 years*

Fish attractors made with synthetic materials

As the focus on impoundment fish attractors has shifted towards specifically designed structures, the use of synthetic materials, such as plastics, has become more common. Synthetic materials are often used to create habitat structures because they are relatively light weight, easy to work with and durable. They offer the ability to create a multitude of fish attractor designs and are often recommended for use in town water supplies because they have little or no impact on water quality. If made from UV stabilised materials, synthetic fish attractors will not deteriorate underwater like timber materials and once installed, can be expected to remain intact and barring damage or removal, provide long-term habitat structure to attract fish. PVC pipe and irrigation tubing form the basis of many synthetic fish attractors because they are cheap, readily available, and can be used to safely make simple, reproducible designs by people with limited construction skills. This makes them excellent for construction by community groups and volunteers of all ages. One of the advantages of pipe-style structures is their relative resistance to entanglement by hooks and lures. The round profile generally causes the hooks to slide over them. Larger diameter pipe is more hook resistant and also has the advantage that fish may utilise the inside of the pipes as well as the spaces between adjacent pipes. Synthetic fish attractors can also be made from flexible components and constructed to minimise the risk of damage or injury if impacted by boats or other water users (e.g. water skiers). Structures made of synthetic materials have sometimes been reported to be slightly less efficient than brush and timber at attracting fish, but this has mostly been related to smaller species and juvenile fish and is likely linked to the larger interstitial spacing typical of this type of attractor. Examples of fish attractors constructed from synthetic materials are given below. This is not an exhaustive list but rather a selection of designs that have proven effective and would be suitable in Australia.

Spiders

Spiders mimic submerged shrubs and consist of 12-20 short lengths of flexible irrigation pipe embedded in a concrete base. Spiders are a cheap and easy way to provide low level fish habitat structure, but their effectiveness is best in shallow waters and adjacent to submerged aquatic vegetation margins. Taller spiders can be made by using stiffer, slightly larger-diameter pipe to create more height. This could improve their usefulness in deeper sites. Spiders are suitable for construction by community groups and can be readily installed from boats of all sizes. They are highly durable and resistant to entanglement of fishing gear. Spiders should be installed in clusters or rows and can be used around other taller fish attractor designs or as linkages between larger structures. They can be used to create shore-based casting lanes.

Spiders waiting to be installed

Pros:	*Inexpensive to construct and deploy, unlikely to shift or release debris, good resistance to fishing gear entanglement, no impacts on water quality*
Cons:	*Provide limited vertical profile, most suitable for only shallow depths, best for smaller fish, many required to create large areas of habitat*
Depth:	*Shallow*

Durability: *Medium to Long term 15-20+ years*

Synthetic trees

Synthetic trees consist of a PVC trunk with multiple protruding limbs of flexible or rigid pipe. The limbs are slotted through holes drilled in the trunk in multiple directions. Synthetic trees can be made in a variety of heights and are anchored in place by a concrete base. If struck by vessels or other water users, synthetic trees may tip over helping minimize injury or damage. The limbs prevent the tree from lying flat, so even at an angle they still provide good fish habitat. Synthetic trees are easily constructed and less likely to entangle fishing gear compared to timber habitats. Rigid limbs are more snag resistant than softer, flexible limbs, which also have the risk of being weighed down by algae and other growth. Synthetic trees are highly suitable for building by community groups, can be readily produced in large numbers and also be made relatively cheaply. If weighted correctly and installed in suitable locations, synthetic trees are unlikely to shift and will not impact water quality. Trees can be deployed from most boat sizes and are best placed in clusters or rows of 5 to 10 structures in medium to deep water depths. The PVC and concrete materials make this type of fish attractor highly durable, although occasionally individual limbs may become dislodged. The structures are relatively open which favours ambush predators.

Pros: *Durable complex habitat, unlikely to shift or release debris, good resistance to fishing gear entanglement, good vertical profile, easy to deploy, no impacts on water quality*
Cons: *May fall on their side or shift slightly in strong currents, limited shade produced*
Depth: *Medium to deep*
Durability: *Medium to Long term 15-30+ years*

Synthetic trees with rigid PVC limbs (left) with flexible upper and lower limbs (right)

Georgia and Shelbyville cubes

Georgia cubes are a fish attractor designed by Georgia Department of Natural Resources. They consist of a cubic PVC pipe frame fitted with lengths of corrugated drainpipe to provide the habitat complexity. The corrugated drainpipe can be either wrapped around the frame or cut into sections and attached. The pipe frames can be filled with gravel or have cement blocks attached to sink and anchor them in place.

Shelbyville cubes are a refinement of the Georgia cube developed by the Illinois Department of Natural Resources. They include the addition of a lower frame or bracing below the drainpipe sections to raise the cubes up off the lake floor. The Shelbyville cubes also include attachment of snow or hazard fencing on the bottom of the frame to discourage settling into the mud and silt. This


A Georgia cube (left) and a Shelbyville cube (right Image: Lake Shelbyville Habitat Alliance)

is optional and not recommended when they are deployed over hard areas. The snow fence has the potential to work loose over time and become a snagging hazard to hooks, lure and passing vessels. The open section created by the additional lower frame provides fish with a shadowed area to occupy beneath the structure. Both types of fish attractors are quick and easy to make and suitable for construction by community groups and volunteers.

If materials are purchased in bulk, cubes can be constructed for a reasonable cost. They are best placed in moderate to deep water in clusters, and have been documented to rapidly accumulate periphyton. The synthetic construction provides good durability and resistance to fishing gear entanglement They are best suited to areas unlikely to experience currents and may require additional anchor weight where currents, strong boat wash or where angler interference is likely. Cubes can be readily deployed off most vessels, but a barge makes installation more efficient. The designs are relatively safe if struck by boats or other water users.

Pros:	*Durable complex habitat, quick and easy to construct, good resistance to fishing gear entanglement, good volume and reasonable vertical profile, lightweight and easy to deploy*
Cons:	*Potential to shift in strong currents if not sufficiently weighted, may be susceptible to anchor damage*
Depth:	*Medium to deep*
Durability:	*Medium term 10-25 years*

Kinchant cribs


Kinchant crib

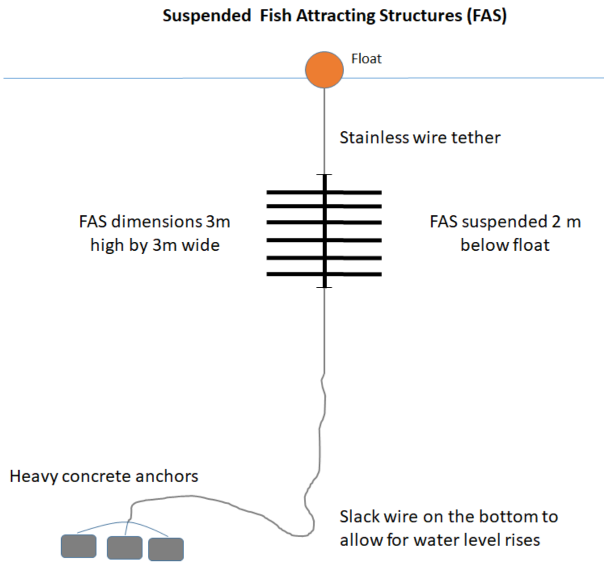
Kinchant cribs were designed as a larger synthetic version of the porcupine crib. PVC pipe instead of solid timber is used to create the layers of the crib and are connected together by heavy duty threaded rod. The crossover points between layers taper inwards in a pyramid shape, increasing stability and creating multiple overhangs for fish to use as ambush points. Kinchant cribs can be made in a variety of sizes, but using 100 mm diameter by 2.0 m long pipe will create structures around 1.5 m high. Concrete blocks or bricks are attached to cross branches to sink and anchor the cribs in place. Kinchant cribs are quick and easy to assemble, highly durable, and contain a greater variety of interstitial spaces due to the hollow pipe ends. They are ideal for construction by community groups and volunteers. The cribs provide a large volume of structural habitat to attract fish without the weight found in solid timber cribs and fish hotels, making them easier to transport and deploy. The PVC pipe makes the cribs very durable, and the large pipe diameter means the structures are quite resistant to hooks and lures becoming entangled. Due to their size and height, Kinchant cribs are best installed in medium to deep water in clusters or rows of 5 to 10.

Pros:	*Good vertical profile and habitat complexity, quick and easy to construct, good resistance to fishing gear entanglement, no leachates or debris*
Cons:	*Moderate expense to construct, requires large vessel or barge to deploy*
Depth:	*Medium to deep*
Durability:	*Medium to long term 20-40 years*

Suspended fish attractors

In Australia the water level in many impoundments fluctuates significantly and strong thermoclines develop at certain times of the year. This situation can lead to some seasonal issues for fish attractors installed on the bottom substrate, including stranding of shallow set structures as water levels drop, or isolation of deep-set structures in zones below the thermocline where oxygen levels are low and fish are less common. Fish attractors suspended in the upper portion of the water column in deeper water can avoid these issues. Such structures would be continuously available to fish, regardless of changes in water levels or thermocline depths. Suspended fish attractors have not commonly been used. The manufacturers of several commercially produced fish attractors suggest their structures can be suspended beneath piers or mounted with an internal float from an anchor on the bottom. However, purposely designed and built surface-suspended fish attractors have rarely been employed in impoundments.

A suspended fish attractor designed and trialled in several Australian impoundments was found to be effective for several fish species. The design consists of an oversized synthetic tree suspended 2 m beneath a surface float and anchored in place with sufficient stainless steel wire cable length to ensure the float remains on the surface at all water levels. This design creates complex habitat, but minimises potential drag on the structure during flow events, ensuring it will not shift. The size of the fish attractor could vary, but the design trialled contains a 3 m long trunk of 100 mm diameter PVC pipe, with 34 x 3 m long PVC pipe limbs inserted in a spiral pattern. The ends of the top few limbs were capped watertight to help the structure achieve only slightly negative buoyancy to reduce the load on the float. A large surface buoy is used to suspend the fish attractor and several connected concrete blocks (total weight 105 kg) anchor the structure in place. Stainless steel wire is used to connect the fish attractor to the anchor weights and float. The wire is highly durable and more resistant to fouling by hooks than rope. The weight of the wire causes any excess to hang vertically when water levels are below full, reducing the risk of fishing gear or boat motors becoming entangled. A swivel is included in the set-up to minimise twisting. It is recommended that plastic mooring buoys be used because they are more durable, retain their colour and will not be broken down or ingested by animals. Suspending the fish attractor 2 m below the surface minimises the risk of collision from vessels or other water users, whilst also placing the bottom of the structure near the thermocline in warmer weather. If made with appropriate materials, suspended fish attractors should be highly durable and last many years with minimal maintenance. The structures can be towed to the installation site before the anchor weights are released.



The main components of a suspended fish attractor

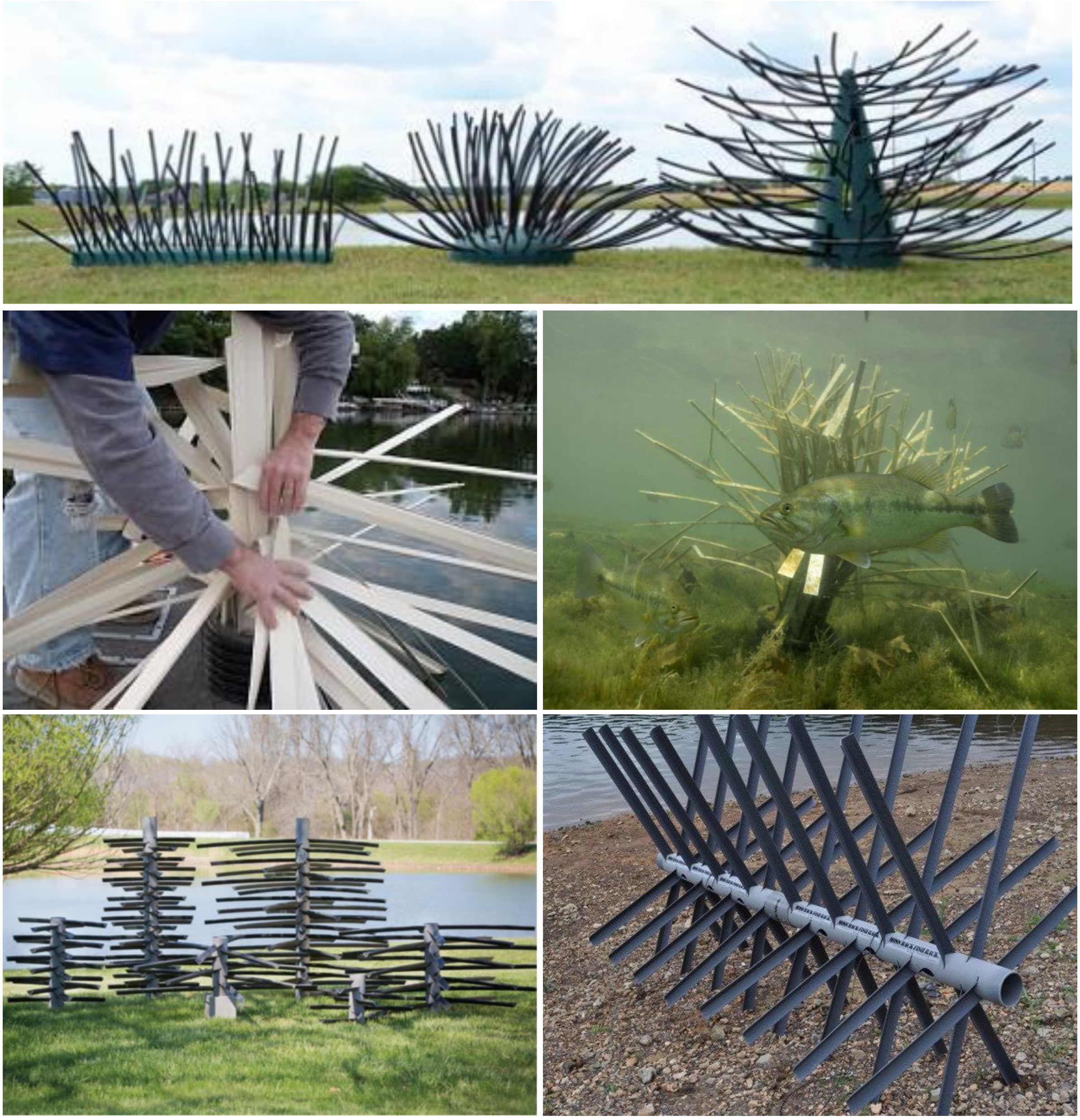
Pros: *Good vertical profile, suitable where water levels fluctuate, remain available to fish regardless of stratification, good resistance to fishing gear entanglement, no debris, no impacts on water quality, visual cue on where to fish*
Cons: *Moderate expense to construct, potential for tampering*
Depth: *Medium to deep*
Durability: *Medium to long term 15-50 years*

Suspended fish attractors assembled (left) and deployed (right)

Commercially available designs

The popularity of habitat enhancement activities in ponds, lakes and impoundments in the USA has resulted in several commercially fabricated fish attractors becoming available. Most structures are made from synthetic materials and come in a wide range of shapes and sizes for different applications. Many are quite light and sold in kit form to make them easy to transport and deploy. Assembly typically involves slotting pieces together to form the desired structure. Advantages of these structures include greater snag resistance to fishing hooks and lures than brush, durability, and the lack of special equipment required to assemble and deploy them. Covering large areas with high densities of commercial fish attractors can be expensive, and therefore they are rarely used for large-scale projects. They are often marketed for installation in small ponds, private farm dams, or under jetties that do not experience much flow. There are currently no distributors in Australia, so all commercial fish attractors would need to be imported from overseas.

Pros: *Complex habitat, easy to construct, reasonable resistance to fishing gear entanglement, no debris, no impacts on water quality, versatile array of designs*
Cons: *Expensive, typically low vertical profile for most designs, currently no local distributors, often not heavily weighted so may shift or be moved*
Depth: *Shallow to medium*
Durability: *Medium 10-40 years*



A selection of commercially made fish attractors: Top row: Pond King; Middle row: Fishiding: Bottom row: Mossback

Fish attractors made with rock and concrete

Fish attracting structures made from rock and concrete are the most durable, but can be expensive and difficult to construct, transport and deploy. The most cost-effective time to install these heavy structures is during low water levels when they can be put in directly via heavy machinery, rather than using large barges. For example, during droughts or when dams are drawn down for maintenance works are ideal times to consider their installation. Alternatively, they could be installed during the construction phase of new dams. The spaces between rocks create gaps with a range of sizes that attract prey species and provide larger fish with ambush opportunities. Large boulders may be needed to create structures with high vertical relief in deeper waters, but mounds and rows can be more easily installed in shallower sites. Care needs to be taken when selecting sites to ensure the weight of the rock does not cause subsidence into the sediment. A base layer of gravel or geotextile fabric may be needed to reduce subsidence. Large concrete rubble can also be used as a substitute for rock. Concrete is best used to create moulded fish attractors that can be designed to suit the requirements of different fish species and locations. One of great advantages of rock and concrete is that, because they are extremely durable, they can be used in impoundments with highly fluctuating water levels. Exposure to air or ultraviolet light will not hasten degradation like it does in timber structures.

Rock piles

Rock-piles installed during dam drawdown: Image: Nebraska Game and Parks

Piles of rock are the simplest rock structure used to attract fish. Creating humps of rock can be a more effective technique than scattered boulders. Piles of rock, stone, and/or concrete that range in type and size are used to provide complex, three-dimensional habitat that will not impact water quality. The gaps between the rocks create refuge and ambush sites for fish. Rock sizes range from fine up to riprap. Rock piles usually contain less than 10 cubic metres of rock rubble and can be built in place during low water levels or deployed from barges. This type of fish attractor is highly durable, but typically only relatively low in height. Traditionally, rock piles are placed on flats or shoals in impoundments. They are also suitable for near shoreline areas, particularly adjacent to points and drop-offs. Rock piles can become navigational hazards if water levels drop, so may require surface markers to indicate their position. Rock piles are most effective at attracting smaller fish and have the potential to help improve the survival of stocked fingerlings. They may be useful sites to release fingerlings into. The crevices enable fingerlings to escape bird and fish predators, particularly in the first few days after release. Rock piles have only limited resistance to fishing gear entanglement, as hooks and lures may get stuck in the crevices between the rocks.

Pros:	*Extremely durable, complex habitat, no debris, no impacts on water quality simple design*
Cons:	*Moderate to expensive to transport and install, low vertical profile, most effective for smaller fish, may require geotextile fabric or gravel base to reduce subsidence, can be vulnerable to long-term siltation*
Depth:	*Shallow to medium*
Durability:	*High 50-100+ years*

Rock reefs

Rock reefs are larger versions of rock piles. They are typically constructed from 10 cubic metres or more of larger rock. Smaller rocks have been found to be more effective at attracting prey species and juvenile sportfish, but fewer large fish. Larger rocks are required to attract larger fish for anglers and mean boulder diameters of 30-100 cm are recommended. The crevices between boulders may also provide suitable habitat for fingerlings, small fish, shrimp and crayfish.

The installation of rock reefs can be logistically difficult and expensive since heavy machinery is required for transport and deployment. The most cost-effective approach is to install rock structures during dam construction or when water levels are low due to seasonal fluctuations or dam wall maintenance. At low water levels trucks can drive right up to a site and either dump the rocks in a pile/line or for larger boulders have the rocks placed in position by an excavator. The size of a rock reefs enables higher vertical profiles which are more effective at attracting sport fish. However, taller reefs pose a greater risk to navigation, and it is recommended that such reefs be installed in deeper water where there is 3-5 m of water above the reef at most times. Surface markers may be required to indicate the site of the reef to assist safe navigation during low water levels. Zones with reduced speed limits for boats would also be suitable for these reefs.

Rock reef with navigational markers (left) and a barge deploying boulders (right, image: Missouri Department of Conservation).

Rock reefs can be installed in lines or broader shapes and designed to be permanently submerged in deeper water, intermittently exposed during water level fluctuations, or partially within and just above the water level. Rip rap used for armouring banks can be highly attractive to fish and such reefs can serve the dual function of minimising erosion and attracting fish.

Linear reefs constructed from rock or concrete extending out from the shoreline can create structures to attract fish across a range of water levels. This design allows anglers to target fish by casting along the rocks. The use of this style of structure could provide long-term fish attraction in impoundments which experience drastic water level fluctuations. The initial installation cost would be high, but they would provide extremely durable fish attractors with no impacts on water quality.

Reef lines are a form of linear reef created on rocky or boulder covered shorelines during low water levels by scraping the rocks along the shoreline into lines extending outward at an angle to the shore. These reefs typically have smaller rock sizes, but can be constructed relatively quickly and cheaply by lighter machinery. They work well in impoundments with seasonally fluctuating water levels.

Rock reefs are the most durable form of fish habitat enhancement and provide long-term benefits. Due to their high installation costs, rocky reefs are mostly recommended for large-scale, well-funded projects where rocks are readily available, or where water levels allow deployment via land.

Pros:	*Extremely durable, complex habitat, no leachates or debris, simple design, suitable for fluctuating water levels, no impacts on water quality*
Cons:	*Expensive to install, may subside on soft sediment, potential navigational hazard*
Depth:	*Shallow to deep*
Durability:	*High 100+ years*


Lines of reef used to provide access for fish to habitat as water levels fluctuate. Images: Missouri Department of Conservation.

Concrete reef modules

Concrete reef modules, such as Reef Balls™ (Reef Balls Foundation, Athens, USA), can be used as extremely durable habitat structures to attract fish. Although most commonly employed in marine environments, concrete reef modules can also be functional in freshwater impoundments. Each module is comprised of a hollow concrete dome, cone or pyramid shape containing multiple openings in the sides to permit fish and other animals to enter. They are constructed from concrete, microfibres and other environmentally safe ingredients that will not negatively affect water quality. Concrete reef modules are quite expensive, extremely heavy, and labour intensive to construct and install. However, they are extremely durable and will not shift. Due to their design, most concrete reef modules deployed from the water surface automatically right themselves, but are typically installed in conjunction with floats, cranes and divers to ensure they are sited correctly. Alternatively, they can be installed using trucks with cranes when water levels are low. Sites need to be carefully selected to ensure the modules are not deployed over soft substrate where subsidence will occur. Installing gravel beds or geotextile fabric beneath the reef modules can help reduce subsidence. Concrete reef modules can be a potential hazard to boaters and other water users if exposed during reservoir water level fluctuations, so they may require navigation markers or be set in deep-water areas that will not be exposed during low water levels. Creating areas with low boating speed limits can also help minimise the risk of collision.

Home-made concrete reef modules (left) and commercially made concrete reef modules (right, image: Reefballs.Org)

Pros:	*Extremely durable, complex habitat, suitable for fluctuating water levels, no debris or impacts on water quality*
Cons:	*Expensive to install, may subside on soft sediment, potential navigational hazard*
Depth:	*Shallow to deep*
Durability:	*High 100+ years*

Concrete pipe reefs

Concrete pipe reefs can also be formed using new or re-purposed concrete pipes, sleepers and large concrete rubble. Combining the rubble and sleepers with the concrete pipes creates habitat with a wide range of holes sizes for fish. The rubble and sleepers prevent the pipes from moving and also create smaller spaces for small fish. The larger openings in the pipe provide habitat for bigger fish, which may use the structure for resting or as an ambush point. The pipe used should be between 450 to 900 mm in diameter. A secondary benefit of installing concrete pipes is their potential as spawning habitat for cod species. Clear evidence of successful spawning has yet to be reported, however monitoring so far has been limited. Further research into how well this approach works is needed. Concrete pipe reefs should be installed at a range of depths to ensure habitat availability as water levels change. Reefs containing one or two pipes are typically scattered in an area to provide multiple sites for fish to inhabit. This is important for territorial species such as Murray cod. Reefs can be placed to enhance existing structural habitat, or they can be used to create new habitat areas. Sites need to be carefully selected to ensure the heavy structures are not deployed over soft substrate where they may sink into the sediment. Laying gravel beds or geotextile fabric prior to installation may help reduce subsidence. The use of concrete provides extremely durable and water-safe habitat structures that will last a long time and can withstand periodic exposure to air as water levels change. The most cost-effective time to install concrete pipe reefs is during periods of low water levels when machinery can be used to put the pipes, rubble and sleepers directly into place. Concrete reef modules can be a potential hazard to boaters and other water users if exposed during reservoir water level fluctuations, so they may require navigation markers or be set in deep-water areas that will not be exposed during low water levels. Creating areas with low boating speed limits can also help minimise the risk of collision.

Concrete pipe reef. Image: G. Ringwood

Pros:	*Extremely durable, complex habitat, suitable for fluctuating water levels, no debris or impacts on water quality*
Cons:	*Potentially cheap to source if repurposed, but transport and installation may require machinery, may subside on soft sediment, potential navigational hazard*
Depth:	*Shallow to deep*
Durability:	*High 100+ years*

Cost effectiveness of different fish attractors

The budget required for fish attractor projects varies greatly depending upon the number of structures to be installed, their type and the size of the impoundment. Large-scale projects can be expensive, especially if all project materials need to be purchased. It is therefore important to consider the initial project budget and longer-term maintenance costs when determining how much a fish attraction project will cost. The relative cost-effectiveness of a fish attractor design is influenced by a number of factors, including how well they work, construction cost, deployment cost and durability. Unfortunately, many previous projects have provided only limited information on the costs associated with construction and deployment.

The most inexpensive fish attractors to construct have generally been those made from recycled pine trees, freshly felled tree tops and brush bundles. These materials are often available locally, minimising transport, and merely require anchor weights to be attached. The materials for some of the PVC fish attractors can also be quite cheap, but the labour involved in construction and assembly is usually higher and increases with structural complexity. A variety of fish attractors are also produced commercially which are typically more expensive to purchase. However, they are designed for easy assembly and installation with basic tools.

Structural durability is a key component in evaluating the suitability of different type of fish attractors for use in Australian impoundments. Durability impacts how the effectiveness of fish attractors change over time, and the period until supplementation or replacement is necessary. Synthetic materials provide long-term durability whilst many structures consisting of natural materials have comparatively shorter lifespans.

The cost for materials to construct individual fish attractors will depend upon how many materials can be donated or recycled, and is likely to range from $6.90 through to over $450 per structure if purchased new (Table 1). The size and volume occupied by individual structures needs to be considered when making comparisons between the costs of different design types. For example, if functionality is ignored, a single suspended fish attractor occupies a volume equivalent to approximately 11 times that of a single spider. Therefore, if you were trying to achieve the same volume of fish attracting structure, it would cost $317.17 for the suspended fish attractor and $147.95 for the spiders.

The labour cost to construct different fish attractors also varies with their design complexity. Structures that are quick and simple to put together or prepare include brush bundles, spiders, felled trees and tree tops. Synthetic trees, porcupine cribs, Kinchant cribs, Georgia cubes and Shelbyville cubes require a little more construction time, but can still be made in good quantities by community groups and volunteers. The suspended fish attractors and fish hotels require more time and effort to construct. Some structures require no construction, but need heavy machinery to transport and deploy. These include tree stumps and rock reefs and piles.

Installation costs vary greatly with the size and weight of the different fish attractor designs. Smaller, light-weight fish attractors such as spiders can be quickly and easily moved around and deployed from most boats. Larger structures may require the use of a pontoon or barge to transport and deploy. This can be considerably more time consuming and expensive, especially if the structures are so heavy they cannot be easily placed into the water by hand. The transport and installation costs need to be taken into consideration when deciding upon the type and number of fish attractors to be used in a project.

Table 1 *Examples of the cost of materials to construct different fish attractor types and the price of commercially available fish attractor kits as of June 2021. All values are in Australian dollars. Note that commercially produced fish attractors currently must be imported, and the listed values do not include shipping. Values adapted from Norris* et al. *(2021). *Where only two values are given for the approximate dimensions, d denotes the diameter.*

FAS design	**Self constructed**	**Commercially produced**	**Approx. dimensions (m)***	**Approx. volume occupied (m^3)**
Brush bundles/tree tops	$6.90-$68.0	-	2.4 x 1.2 x 1.0	2.88
Timber cribs	$132.75	-	1.2 x 1.2 x 1.0	1.44
Spiders	$13.45	$54.40-$257.04	0.6 x 2.0*d*	1.88
Synthetic trees	$70.32	$176.80-$408	2.0 x 2.0*d*	6.28
Georgia cubes	$64.52-$114.98	-	1.2 x 1.2 x 1.2	1.73
Suspended FAS	$317.71	-	3.0 x 3.0*d*	21.21
Fish hotels	$500	-	2.4 x 2.4 x 1.5	8.64
Reef balls		$136-$612	1.2 x 1.2 x 1.0	1.44
Synthetic horizontal fence		$30.6-$224.4	2.0 x 1.5*d*	9.42
Porcupine pyramids		$59.84-$81.6	1.65*d* sphere	2.25
Synthetic stumps & shrubs		$81.6-$272	Varies	2.31

Planning a fish attractor project

A strategic approach to planning and development is essential to ensure impoundment fish attractor projects are undertaken safely and effectively. We recommend the following steps are followed:

1. Set clear project objectives
2. Undertake baseline surveys of the fish and existing habitat distributions
3. Determine the dam hydrology
4. Seek stakeholder input
5. Develop a fish attraction plan
6. Obtain necessary permits and approvals
7. Construct and deploy the fish attractors
8. Make the information available to anglers
9. Monitor the results
10. Maintenance
11. Review the fish attraction plan

These steps are outlined in more detail in this section.

1. Setting clear project objectives

A key criterion to successfully using fish attractors is to set clear and realistic objectives about what you want to achieve at the commencement of the project. Clear strategic objectives and targets will help determine the types, quantity and placement of fish attractors and how to know if they are achieving the desired results. Clearly outline what the project hopes to achieve in as much detail as possible.

Possible objectives could include:

- creating new fishing hotspots
- improving existing fishing sites
- increasing angler catch rates
- attracting fish to sites closer to boat ramps to reduce travel distances for boats and kayaks
- attracting fish to sites where anglers can fish from the shore
- attracting fish to sites away from closed zones and dam infrastructure into areas where anglers are permitted to fish
- increasing survival of stocked fingerlings

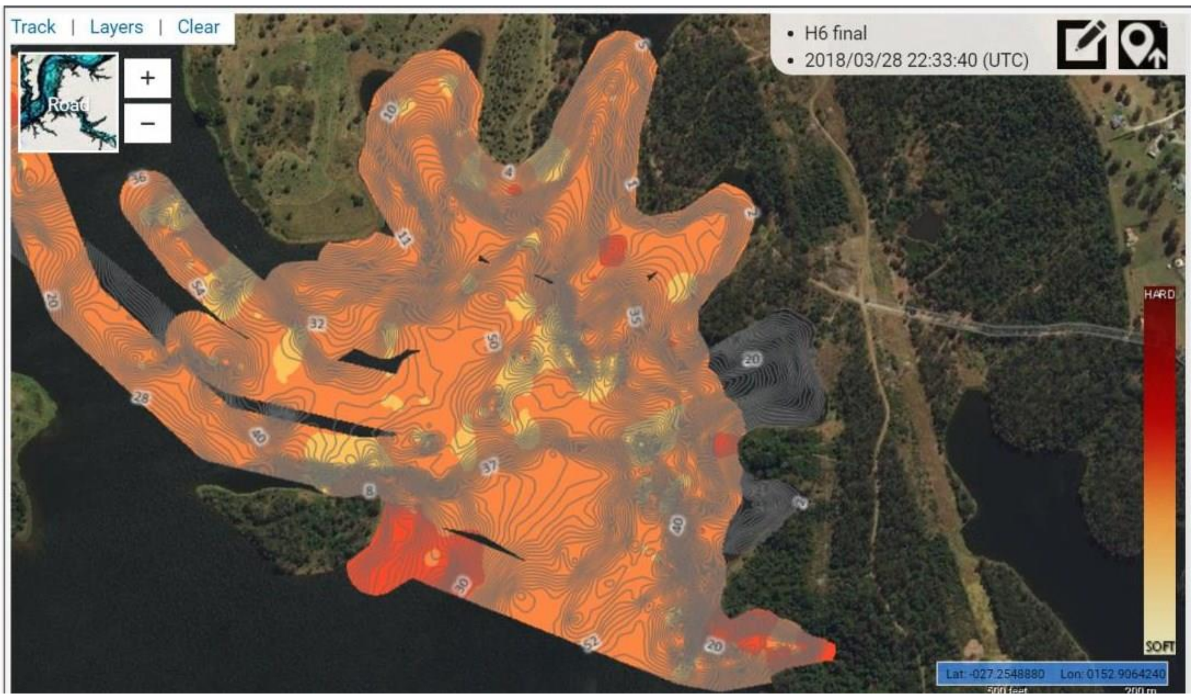
The objective of a project has a large bearing on the amount, type and deployment patterns of fish attractors. Whilst fish attractors can concentrate a fish population, too many fish attractors could again dilute the local density of the target species, especially if there is already some high-quality fish habitat in the impoundment. In general, if the objective is to create an opportunity for many anglers to catch at least a few fish, then installing a smaller number of fish attractors at more sites could be considered. This strategy allows for structures in more locations around the impoundment. It should disperse the overall concentration of fish and still afford smaller concentrations at the fish attractors. A drawback to this strategy is that unless the structures are marked, anglers may find them difficult to locate. If the goal is to create high quality fishing hotspots, then installing fewer larger structures (such as a field of fish attractors) may be more appropriate. Such spots could be created from multiple large fish attractors or consist of a broad field of many structures. Larger structures may attract more fish, increasing the possibility of angler success and are easier to locate. However, with fewer sites containing fish attractors, not as many anglers may be able to use them at the same time, and in busy dams some fishers may miss out.

2. Baseline surveys

The next step in a fish attractor project is to determine the current fish distribution and availability of existing habitat. This baseline assessment will identify key areas that could benefit most from fish attractor installation and inform the development of a Fish Attraction Plan. The information collected will enable specific and targeted project objectives to be developed and form baseline data against which project progress and success can be measured.

If no recent surveys of the fish community have been conducted, we recommend that trained professionals be engaged to survey the impoundment. The fish survey should focus on the population structure of the fish species targeted by anglers, as well as the prey species for these fish. This information will help identify the species likely to benefit the most and help decide upon the most suitable fish attractors to install.

Surveying existing habitat can establish the extent of structure availability and whether the scarcity of structures and bottom profile is potentially limiting fishing opportunities. A contractor could be engaged to survey the existing habitat in an impoundment, but the process can also be accomplished by stocking and angling groups who have access to quality sounders on their boats. The side-scan features on newer sounders can capture images of structure in wide swaths on both sides of the boat, and associated software can link these images to map the underwater topography. This software can also be used to identify individual habitat structures such as submerged trees, map aquatic vegetation or map the substrate hardness. The latter is important because it identifies areas of soft substrate where fish attractors may subside into the sediment. This can also be achieved, but much more slowly, with less sophisticated sounder units without side-scan functionality.



An example of a bottom hardness map from North Pine Dam. Darker red indicates harder substrate. Image: N. Frost

3. Determine dam hydrology

A clear understanding of a dam's hydrology is necessary to determine where and at what depths fish attractors should be installed. Investigating water levels trends over the past 10 to 20 years will enable the best depth ranges to be identified. One option to ensure the fish attractors remain functional and minimise the risk of becoming a navigational hazard is to use the minimum water level at which the fish attractors would be covered for at least 75% of the time. In dams which fluctuate only a small amount, structures should be covered for a greater proportion of the time. Conversely, in dams where water levels fluctuate a large amount over time, structures may only be covered for a lower proportion of time., and some fish attractors may need to be placed in depths where they may be too deep or out of the water at times to ensure that structure is available at a range of water levels.

Another important aspect of looking at dam hydrology is understanding likely current patterns when water inflows occur. Areas that will likely experience high currents should not have fish attractors installed because there is a greater risk of them shifting or accumulating debris. Understanding current patterns will also help determine the necessary anchoring weights for fish attractors deployed in different areas.

4. Stakeholder consultation

A broad range of stakeholders should be consulted during the development of a fish attractor project. Widespread engagement with people or groups who are likely to be involved in, or potentially impacted by, the installation of fish attractors is important to ensure common goals can be set and potential issues are addressed or avoided. Stakeholders could include local angling and fish stocking groups, the waterway operators, fisheries managers, and other businesses who operate on the impoundment. Other waterway user groups such as boating, water-skiing clubs, kayaking and rowing clubs may also be impacted by the installation of fish attractors and should be included in the consultation process. One way to maintain meaningful engagement is to establish a project steering committee to encompass the views of the stakeholders and other interested parties, and to provide an avenue for information dissemination.

5. Developing a fish attraction plan

A fish attraction plan clearly documents the details of a fish attractor project. The plan outlines the need for the project, defines the objectives and a provides a blueprint of the proposed activities to be undertaken. A comprehensive fish attraction plan will enable regulatory bodies and the waterway manager to assess the value of a fish attractor project and ensure all risks have been suitably addressed. This section contains the key factors that need to be considered when developing a fish attraction plan.

5.1. Selecting the types of fish attractor to use

The type of fish attractors selected for use will depend upon a number of factors, including the project objectives, species being targeted, budget, means of deployment, availability of materials and the types permitted for use by the impoundment operator. A wide range of fish attractor types have proven to be effective in different scenarios, and there is currently no clear consensus on which designs or materials are most effective. A combination of fish attractor designs will provide the best range of habitat complexity and is most likely to attract a broader range of fish species and sizes. The descriptions of the different fish attractor types earlier in the guideline and the species suitability table in Appendix 2, contain information to help select which designs to use in particular situations.

One important aspect of fish attractor design that should be taken into consideration is how much vertical profile they produce. It has been found that structures which provide greater vertical profile are generally more attractive to most fish. In the USA, it has been suggested that fish attractors should occupy at least one-third of the water column where possible. Where feasible, taller and larger structures should be used in deeper water, whilst lower profiles are more suited to shallower depths.

Fish attractors constructed from synthetic materials are preferred for some projects because they have no impact on water quality in impoundments which supply town water, and there is little risk of debris being released that could clog offtake towers or damage other dam infrastructure. Additionally, fish attractors made from synthetic materials may be more cost effective in sites where timber or rock materials are not locally available.

5.2. Location

The locations where fish attractors are installed plays a very important role in how effective they are. Exposure to current, substrate type, proximity to other habitat, water depth, water level fluctuations and proximity to angler access points all need to be taken into consideration.

5.2.1 Substrate type

Knowledge on the substrate characteristics at potential sites is crucial prior to deployment of fish attractors. The baseline sonar surveys can be used to determine areas where the substrate is comprised of soft sediment and areas where the bottom is harder. In general, it is best to avoid placing fish attractors in areas with deep, soft sediment. Such sites often occur where inflowing gullies and creeks form deltas where sediment is dropped out of suspension as water velocity slows upon entering the dam. At these sites heavier structures will subside into the sediment over time and become less effective. Additionally, accumulation of further sediment may smother fish attractors, reducing their effectiveness. Where only a moderate layer of sediment occurs over a hard bottom, installing a base of gravel prior to deploying the fish attractors can help reduce subsidence.

The habitat preferences of the target species for the fish attractors also need to be taken into consideration. Some fish species prefer different substrates to others, and this may vary at different times of the year. For example, golden perch and Murray cod prefer rock and rubble compared to bare sediment, whilst eel-tailed catfish can be found in areas with both substrate types. Fish attractors should be installed over substrate where the target species are likely to occur.

5.2.2 Proximity to existing habitat and structure

The location of fish attractors should be tailored to the behaviour of the fish to be attracted. Fish attractors can be used to create new habitat in the middle of areas devoid of structure, or they can be used to enhance the fish attracting ability of sites which already have some structure present. If fish are known to traverse areas with little structural complexity, adding fish attractors can act like a bus stop. Fish moving through may pause to rest or feed at the fish attractors before moving on. This gives the anglers a greater chance of locating and catching widely dispersed fish. For this approach to be effective, the fish attractors must be installed in or near to areas where fish are likely to move through.

Alternately, fish attractors can be installed adjacent to existing structural features such as old creek beds, gullies, rock walls or submerged points. The fish attractors will provide additional cover for the fish already utilising these areas, encouraging them to stay longer. Near steep drop-offs, fish attractors should be placed along the top edge of the shelf before the slope drops away. Fish moving along the drop-off, as well as those already foraging on the shelf, will use the fish attractors as ambush points. Using the top of the drop-off also locates the fish attractors at a shallower depth reducing the risk of them becoming positioned below the thermocline in warmer months.

Deeper holes in old creek beds and gullies can also be great spots to install fish attractors, particularly if the water levels are less than 10 m deep. However, care needs to be taken to ensure that currents during inflow events are not too strong and likely to cause the fish attractors to shift. Suspended fish attractors can be a great way to provide structure over old creek beds in deeper water. This technique should work well for species such as Australian bass and barramundi which occupy such areas at certain times of the day or year.

Fish attractors should be placed away from dam infrastructure, particularly if they are directly upstream during flow events. This helps mitigate the risk of fish attractors shifting and potentially damaging dam infrastructure.

5.2.3 Proximity to angler access

Angler access should be considered when selecting sites for fish attractor installation. Fish attracting structures hold the potential to help manage where anglers fish and improve angler access to fish. Some of the best habitat for fish can be found around dam walls and offtake infrastructure. Unfortunately, these areas are often closed to angler access. Fish attractors can be used to provide additional areas of high-quality fish habitat away from the closed zones. Attracting fish to such sites may reduce the frequency of anglers illegally fishing in closed zones. Fish attractors could also be used to attract fish closer to boat ramps or launch sites. This would help encourage anglers to fish closer to where they launch and potentially reduce the impacts of erosion from boat wash and pollution from outboards. Such an approach would also benefit kayak and canoe anglers who wouldn't need to paddle as far.

Shore-based anglers are often restricted in the places where they can fish, and access points do not always coincide with prime fish habitat areas. Installing fish attractors to attract fish to points where shore fishing is allowed could improve fishing and encourage anglers to remain within permitted zones. Mobility limited anglers could especially benefit from this approach if fish attractors were installed adjacent to parking areas with easy shoreline access.

5.2.4 Water depth

Fluctuations in water levels make it difficult to install fish attractors at precise depths, but low to moderate periodic or seasonal fluctuations can readily be accounted for. To be most effective, some fish attractors should be placed above the summertime thermocline, particularly if the lower layer of water develops low oxygen levels. The best depth range for most structures is 4 to 10 meters depending upon the structure height and water level fluctuations. Good results often occur when structures set in these depths are located adjacent to deeper water. The vertical relief provided by a fish attractor has been found to be an important factor in how effective a design is, and ideally the fish attractor should cover one-third of the water column or more. Taller fish attractors are therefore more effective in deeper water. Structures with high vertical relief can be set in very deep water to create fishing hotspots, but these are likely to only attract fish when there is no strong thermocline in the cooler months and become fishless in summer when the thermoclines develop.

The goal of the fish attractors needs to be taken into consideration when selecting the installation depth. If the objective is to provide habitat for a given species, the preferred depth range of that species can be factored into where the structure is placed. A range of depths may be needed to ensure fish attractors are set in appropriate locations and depths for a seasonal movement patterns and behaviours. The results from the Cressbrook Dam project and Lake Samsonvale trial suggests structures set at all depths are likely to be used by Australian bass and golden perch. Both deep and shallow fish attractors were used at different times of the year. In Kinchant Dam, barramundi were using fish attractors set from 3 m deep through to a surface suspended fish attractor set in 11 m of water.

Fish attractors set in very shallow water face the risk of becoming stranded if water levels drop, becoming navigational hazards or becoming overgrown by aquatic vegetation.

5.2.5 Avoiding navigational hazards

Fish attractors can potentially create navigational hazards if not installed in the right locations. The depth of the fish attractors needs to be sufficient to allow for safe navigation over the top, ideally at the lowest water level. The required clearance (i.e., minimal water depth above the reef) depends on the location and anticipated type of traffic that would traverse the area, but should be greater than 1-2 m where possible. Examining the historic water levels in the dam will provide an indication of what water depths to use when water levels fluctuate. Where the fluctuations are large, some fish attractors may need to be placed in depths that have the potential to create navigational hazards, in order to provide suitable fish habitat above the thermocline in warmer months. In such instances the fish attractors should be located in areas with restricted speed limits, or away from main traffic routes, ideally contained within bays. Special marine hazard markers may also be needed to indicate the potential navigational risk to vessels.

5.2.6 Dealing with fluctuating water levels

One of the key issues for the use of fish attractors in Australian impoundments has been how they could be effectively used where water levels fluctuated substantially. This was identified as one of the top five priorities for research in a survey of Australian researchers, managers and other stakeholders (Norris 2016). Many Australian impoundments periodically release large amounts of water for irrigation, which can lead to significant fluctuations in water levels. Other impoundments only experience intermittent filling events, with water levels declining steadily in between (e.g. Cressbrook Dam). The main issues where water levels vary include fish attractor degradation due to exposure to air and the wetting and drying cycle, fish access to fish attractors, tampering with structures, visual aesthetics if attractors are exposed and risks to navigation. These potential issues can be overcome through the appropriate selection of materials, designs and deployment sites.

If habitats are placed in waters deep enough to prevent being exposed during even the most extreme drawdown, they may end up in the anoxic zone during stratification in warmer months. The use of structure lines extending from the shoreline into deeper water can provide habitat to attract fish across a range of water levels. Materials used to construct such structure lines need to be durable to exposure. Rock and concrete are the most durable, but the ease and cost of installation may prove prohibitive in some scenarios. Fish attractors constructed from hardwood timber or UV resistant PVC could also be used where exposure is expected. These materials will tolerate repeated exposure, but their functional lifespan may be decreased. The type of fish attractor used would also need to be robust. Broad based structures, such as timber or heavy-duty PVC cribs, would be more suitable than synthetic trees or Georgia cubes. The risk to navigation from lines of structures could be reduced by labelling the shoreward extent with a sign and the open water end with a marker buoy. This would provide waterway users with a visual reference of where the fish attractors are. If the reef line is very long, intermediate buoys may be required. Identifying the extent of the reef with signs and buoys has the added benefit of informing anglers exactly where the structures are so they know where to cast.

An alternative approach is to use fish attractors suspended from the surface. This has the advantage of maintaining the structure a set distance below the surface, keeping them above the thermocline and ensuring year-round access regardless of dam stratification. Placing suspended structures at least a metre or more below the surface reduces the risk of collision by vessels and water users. This is particularly important in multi-use dams with water skiers, wake boarders and tube riders.

5.3. How much to install

The quantity of fish attractors needed for a project should only be determined after estimates of the existing structure are determined through surveys. The number of fish attractors required will depend upon the project's objectives, the size of the impoundment, the size of fish attractors used, restrictions from waterway operators, and the budget available.

In general, the average number of individuals and species of fish attracted increases with the structural complexity achieved by increasing the volume, size, and surface area of fish attracting structure. Larger structures typically provide the best increases in angler catch rates. Some habitats may support fewer, larger predatory fish, while others may support more numerous, smaller individuals. Territorial species such as Murray cod, may do better when there are multiple smaller clusters of structure which can provide more fish with their own area. This could increase the carrying capacity for such species if sufficient suitable habitat was not already present.

Information on the optimal quantity of fish attractors to install is still limited, but will depend on the overall project objectives. For example, if the management goal is to create an opportunity for many anglers to catch at least a few fish, then installing many fish attractors in small clusters could be considered. This strategy allows for fish attractors in more locations around the impoundment. It should disperse the overall concentration of fish and still afford smaller concentrations at the fish attractors. One drawback to this strategy is that unless the structures are marked, anglers may find them difficult to locate.

If the objective is to create an opportunity for anglers to catch high numbers of fish, then installing fewer, larger groups of fish attractors may be more appropriate. Larger structures are likely to attract more fish, increasing the possibility of angler success. Another advantage of larger structures is that they are easier to locate. Larger structures may be an aggregate of smaller individual units or based on fewer larger fish attractors. The downside of larger fish attractors is that fewer anglers can fish a spot at one time, leading to some anglers not being able to access the site or preferring to fish in quieter areas.

The size of an impoundment and the amount of structure required to achieve the project objectives need to be carefully considered in the planning process. It is more economically and logistically feasible to achieve positive results in smaller impoundments rather than large impoundments. In larger waterbodies, the scale may necessitate that fish attractors are only used to improve angling in isolated sections, such as selected bays, points or arms.

5.4. Deployment configuration

The deployment configuration and size of the area covered by fish attractors impacts how well fish are attracted to an area. The pattern of fish attractor deployment in relation to other nearby habitat may also influence the number and size of fish attracted to a site. The number of fish attracted to a site is generally higher when fish attractors are clustered rather than placed in isolation.

The number of fish attracted has been found to vary between fish attractor configurations with different degrees of openness. The general consensus is that more open deployment configurations attract fewer larger fish, whilst more compact and dense configurations attract more, but smaller fish. Fish attractors grouped by rows compared to clusters produce more fish and it is suggested this configuration provides continuous habitat used for better orientation and cover. Fish attractors deployed in a circular pattern minimise the amount of edge and maximise the amount of interior cover, and have been reported to attract more, but smaller fish than those attracted to a linear design. In the USA, discrete open-centred structures attract more smallmouth and largemouth bass than structures placed in a dense-linear, or continuous open-centred arrangements. However, the larger fish preferred the more open configurations. The results from these studies suggest that fish attractor configuration has the potential to influence the number and size of fish attracted to a site. At sites established to improve family fisheries (higher catch, but typically lower size), fish attractor deployment configurations utilising discrete open centres (circular or square) could be used to attract more, but smaller fish, whilst more linear configurations could be employed to attract fewer but larger individuals for trophy sites.

5.5. Monitoring and evaluation

It is extremely important to monitor the impacts of the project to determine if the project goals are being achieved. On-going monitoring informs management decisions and allows successful approaches to be applied more widely, while unsuccessful approaches can be refined or discontinued. The techniques used for monitoring and evaluating the project should be clearly outlined in the fish attraction plan.

Common options for monitoring changes in angler catch rates include creel surveys, angler diaries, and standardised fishing surveys. In addition to understanding how angler catch rates change, it can be very useful to also monitor the attitudes of anglers towards the fish attractor project and if their level of enjoyment or frequency of fishing have changed. Surveying anglers at the boat ramp is a very effective way to do this. Counting the number of boats using a dam or identifying whether they were fishing on the fish attractors are other possible ways to monitor angler effort. These monitoring tools will allow a better understanding of the fishing pressure at the impoundment and give an indication if the number of fish caught or taken home by anglers has changed. This has important implications for management to ensure the impoundment is stocked appropriately and not over-fished.

The distribution of fish in the impoundment and how they are using the fish attractors should also be monitored. This can be slightly more difficult and may involve engaging fisheries agencies or consultants to periodically conduct fish surveys. Most modern sonar units have the capacity to detect individual fish and can be used to assess how fish use the different types and locations of fish attractors. This approach is suitable for fish stocking, angling and other community groups.

Good quality sonar units can also be used to monitor the condition of the fish attractors. This is particularly important if natural materials are used, so degradation can be monitored. The sonar can determine the current condition of the structures, and identify fish attractors that need to be replenished or supplemented to remain effective.

Underwater cameras can also be used to monitor both fish use and the condition of fish attracting structures. Water clarity can vary greatly in impoundments, potentially making it difficult to consistently collect monitoring information this way. However, where it is clear enough to use cameras, detailed information and fish counts can be recorded and images collected are a great way to show what has been done and how it is working. This can be especially useful to generate interest on social media platforms.

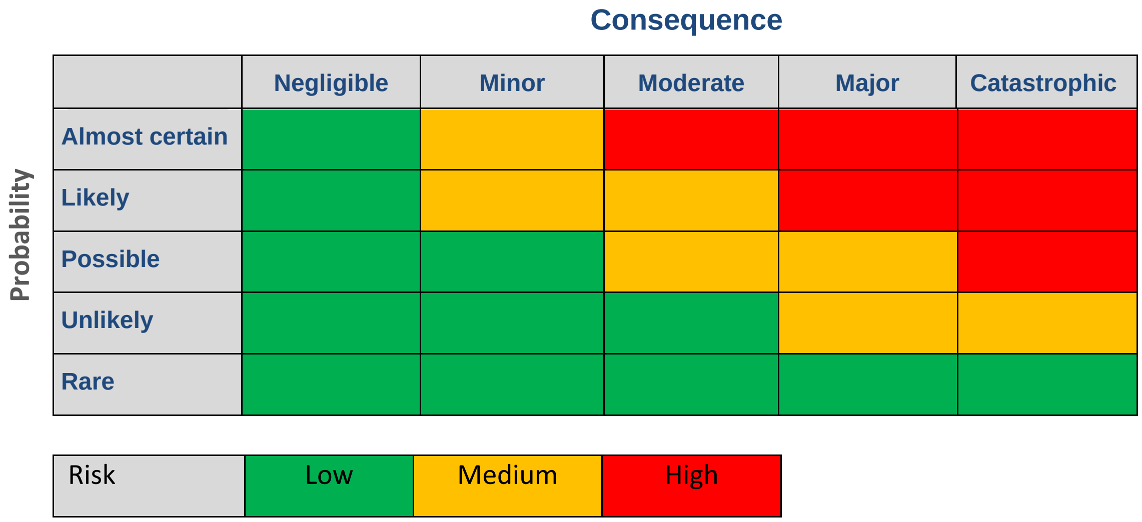
The results from the monitoring and evaluation should be used to refine the fish attraction plan in order to obtain the best results.

5.6. Risk assessment

A risk assessment for installing fish attractors should be conducted as part of every fish attraction plan. Risks that need to be considered include potential damage to dam infrastructure, navigational hazards, contamination of water or the aquatic environment, impacts on town water supply quality, increased pressure on fish stocks, and impacts on other waterway users. A standard two-variable risk assessment matrix (5 x 5) using likelihood and consequence ratings will help identify any risks which need to be mitigated. The steps to risk assessment include:

1. List all of the potential hazards
2. Assess the likelihood and consequence of those hazards
3. Evaluate the risk and determine if they need to or can be mitigated or reduced
4. Revise the risk matrix with mitigation practices in place
5. Respond to the final risk - accept, reduce, avoid

Many examples of risk assessment matrices and risk mitigation are available on the internet. An example of a basic risk matrix is contained below. Low level risks are generally acceptable, but it may be possible to eliminate them completely. All medium and high risks will need to be addressed and actions put in place to minimise them. See Appendix 3 for a real example.



6. Obtain permits and approvals

A range of permits and approvals will be needed to install fish attractors in an impoundment. Most waterways are owned and operated by a specific organisation, who are responsible for activities in that impoundment. It is essential that written approval be obtained from the impoundment operator prior to the installation of any fish attractors. Before developing a project proposal, discussions should be had with the operator to ascertain whether fish attractors will be allowed, suitable types that could be used and permitted locations for installation. These discussions will also help development of the fish attraction plan.

Fish attractors have the potential to impact navigation, and, in some areas, permission may be needed from the local maritime safety authority to place structures into the water. These organisations may also have requirements on the types and sizes of buoys to be used and whether they require lighting for night-time navigation. In some circumstances, creating go slow areas (6 knots or less), can be a way of minimising the risk of high-speed collisions with fish attractors and anglers fishing around them. The maritime safety organisation and impoundment operator should be able to assist with such arrangements. In some areas, permits may also be required from fisheries agencies before structures can be installed.

Written approval of the fish attraction plan by the waterway operator, key stakeholders and other key regulatory bodies must be achieved before any fish attractors are installed.

7. Constructing and deploying fish attractors

Once the fish attraction plan has been completed and approved, construction and deployment of the fish attractors can commence. It is very useful for fish attractor projects if secure storage and workshop areas can be organised near the impoundment. Materials can then be delivered and stored in a safe location and the finished fish attractors will not have to be transported far for deployment. It may be worth contacting the waterway operator to see if a temporary storage site can be organised.

Heavy materials such as rock, concrete, tree stumps and large trees are best stored as close as possible to a loading site near the water's edge to minimise transport. Brush piles and tree tops will need an area to be stored and prepared as they are accumulated. Note that brush can make a significant mess if left too long and the leaves drop off. Lighter, modular structures can be fully assembled at a workshop area, or they can be transported in pieces and assembled at the loading point.

The worksite where the fish attractors are to be constructed should be flat and, if possible, have access to power, water and shade. This will enable a range of power tools to be used to speed up the construction process. One efficient way to construct fish attractors is to hold working bees. Anglers are often interested in becoming involved in projects to improve the fishing at impoundments they visit. Other community groups such as Lions, Rotary or scout groups may also be interested in helping with the project. Advertising a working bee may encourage anglers and other volunteers to assist with the transportation, construction and deployment processes. It is important that during fish attractor construction safety regulations are followed and all persons use suitable personal protective equipment for the tasks they are performing.

Deploying Georgia cubes from a barge

Deploying fish attractors can range from relatively easy to quite difficult and expensive, depending on the size and weight of the designs chosen. Smaller structures like spiders, brush bundles and synthetic trees can be easily deployed from most vessels, but larger structure such as fish hotels, whole trees and rock may require specialised barges. For larger projects, the cost of contracting a small barge should be considered to make installation of fish attractor safer and more efficient. The cost may offset the time, difficulty and safety issues of trying to transport and deploy larger fish attractors from smaller vessels. In the USA many fish attractor projects use dedicated flat-deck barges with hydraulic tilts to install their structure.

In impoundments where large distances need to be covered, or only electric motors are permitted to be used, it may be more efficient assemble structures at areas close to where they will be deployed. This minimises the time spent travelling with the larger assembled structures and can greatly speed up the installation process.

It may be helpful to pre-mark the fish attractor sites using marker buoys to ensure accurate installation. A single marker could be used to indicate the centre point around which structures will be placed, or several markers could be used to indicate the outer extent of the deployment site. Marking the site will help minimise deployment of fish attractors on top of other structures, which may not always be desirable.

The location of all fish attractors should be recorded along with parameters such as the type, size, deployment date and water depth.

8. Extending information

The location and details for fish attractors should be made available to the public to encourage their use. The location of installed fish attractors can be marked with buoys or signs attached to trees or posts on the shoreline above maximum water level, to indicate the nearby presence of installed fish habitat. Labelling the fish attractor sites makes it easy for anglers to visually identify where habitat has been placed so they can target that area. Not all anglers have access to a boat or kayak with a sonar or GPS unit. The buoys and signs not only indicate sites for anglers to fish, but they let other waterway users know that structures have been placed in the area and to take care. They also are a useful way to inform people about the work that has been undertaken and provide acknowledgement to sponsors who have helped make it possible. A disadvantage to marking habitat structure locations is that too many anglers may concentrate their efforts in just a few places, increasing the possibility of localised overharvest. An option to prevent this problem would be to mark some structures, but not all, or to put in enough structures that over-targeting is unlikely. The buoy shape, colour, or both should be different from buoys with navigational significance. Buoys constructed from solid coloured plastic are generally best as opposed to painted buoys, because the paint will degrade from sun exposure and wave action. Foam floats may also break down over time.

Information on the location and details of fish attractor sites can also made available to anglers via signage at boat ramps, a website, phone app, interactive online maps or paper charts. Creating a website where anglers can download the GPS coordinates, fish attractor details as well as a PDF map of their locations in the impoundment has proven to be very effective and popular overseas.

The use of buoys, signs, webpages and maps are highly valuable tools to increase the success rate of visiting anglers who may not know a reservoir very well. This is particularly true for learner anglers or tourists who hire smaller boats which may not necessarily have a quality sounder or GPS unit. These anglers can use the map to drive to an area where habitat installations should attract fish and wet a line with the knowledge they are fishing in a likely spot.

Examples of surface markers and signage to indicate where fish attractors are located.

9. Monitoring

Monitoring and evaluation should be conducted as outlined in the fish attraction plan. At a minimum monitoring should occur once per year. The monitoring results can be used to encourage people to use the fish attractors and potentially attract additional anglers to the impoundment. Monitoring also provides an opportunity to determine the status of the fish populations in an impoundment and help with stocking management decisions.

10. Maintenance

Most fish attractors should require very little on-going maintenance. Less durable structures, such as brush bundles, will require periodic supplementation in order to remain effective as they break down over time. The monitoring should give an indication of when this is required. Additional structures can then be placed onto the site when needed. In synthetic structures, limbs might occasionally get removed by anglers, but are unlikely to need replacing unless substantial damage to the fish attractor has occurred. For the more complex suspended fish attractors, maintenance may occasionally be required on the surface buoy to ensure that it remains highly visible and keeps the structure suspended. Some structures may occasionally get moved by people, particularly if they anchor around the fish attractors. Where possible, any shifted structures should be returned to their original sites, so anglers know where to fish.

11. Review

It is important to review the fish attraction plan regularly. The results of the monitoring and evaluation may indicate that certain fish attractors or locations are working well and that others are delivering less than expected results. Long term changes in water levels due to ongoing drought or lowering of the supply level of the dam may necessitate altering the proposed locations for some fish attractors if they have not already been installed. Low water levels may also provide an opportunity to construct some heavier fish attractors directly on the exposed bank. During the review process, the fish attraction plan can be refined to capture this knowledge and capitalise on opportunities to improve the outcomes of the project.

References and further reading

Allen, G.R., Midgley, S.H. and Allen, M. (2003) *Field guide to the freshwater fishes of Australia.* Western Australian Museum, Frances Street, Perth. 411 pp.

Bolding, B., Bonar, S. and Divens, M. (2004) Use of artificial structure to enhance angler benefits in lakes. *Reviews in Fisheries Science.* 12: 75-96.

Houser, F. (2007) *Fish habitat management for Pennsylvania impoundments*. Pennsylvania Fish & Boat Commission, Bellefonte, Pennsylvania. 44 pp.

Hutchison, M., Gallagher, T., Chilcott, K., Simpson, R., Aland, G. and Sellin, M. (2006). Impoundment Stocking Strategies for Australian native fishes in eastern and northern Australia: With an assessment of the value of scales as tags for barramundi. Final report to FRDC for Project No. 98/221. Department of Primary Industries, Brisbane. 146 pp.

Jackson, D.A., Peres-Neto, P.R. and Olden, J.D. (2001) What controls who is where in freshwater fish communities: the roles of biotic, abiotic and spatial factors. *Canadian Journal of Fisheries and Aquatic Sciences* 58(1): 157-170.

Johnson, D.L., Beaumier, R.A. and Lynch Jr, W.E. (1988) Selection of habitat structure interstice size by bluegills and largemouth bass in ponds. *Transactions of the American Fisheries Society* 117:171-179.

McCartney, M., Funge-Smith, S. and Kura, Y. (2018) *Enhancing fisheries productivity through improved management of reservoirs, dams and other water control structures*. CGIAR research program on fish agri-food systems, Program brief: Fish-2018-11, Penang, Malaysia. 16 pp.

Miranda, L.E. and Pugh, L.L. (1997) Relationship between vegetation coverage and abundance, size, and diet of juvenile Largemouth Bass during winter. *North American Journal of Fisheries Management* 17: 601-610.

Norris, A. (2016) *Increasing Australian impoundment fisheries potential: Habitat enhancement to improve angling and productivity in impoundments*. Winston Churchill Fellowship Report, Winston Churchill Memorial Trust of Australia, Canberra. 101 pp.

Norris, A., Hutchison, M., Nixon, D., Shiau, J., and Kaus, A. (2021) *Freshwater fish attracting structures (FAS): Evaluating a new tool to improve fishing quality and access to fisheries resources in Australian impoundments*. FRDC Project 2017-019. Department of Agriculture and Fisheries, Brisbane. 201 pp.

Norris, A., Nixon, D. and Hutchison, M. (2020) *Kinchant Dam fish habitat enhancement project: Final report*. Department of Agriculture and Fisheries, Brisbane, Queensland. 28 pp.

Pardue, G.B., and Nielsen, L.A. (1979) Invertebrate biomass and fish production in ponds with added attachment surface. Pages 34–37 in D.L. Johnson, and R.A. Stein (eds). *Response of Fish to Habitat structure in standing water*. North Central Division, American Fisheries Society, Special Publication 6, Bethesda, Maryland.

Rochman, C., Hoh, E., Kurobe, T. and Te, S.J. (2013) Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports* 3: 3263-3269.

Tugend, K., Allen, M.S. and Webb, M. (2002) Use of artificial habitat structures in U.S lakes and reservoirs: A survey from the southern division AFS Reservoir Committee. *Fisheries* 27(5): 22-27.

Wege, G.J., and Anderson, R.O. (1979) Influence of artificial structures on largemouth bass and bluegills in small ponds. Pages 59-69 in D.L. Johnson, and R.A. Stein (eds) *Response of fish to habitat structure in standing water*. North Central Division, American Fisheries Society, Special Publication 6, Bethesda, Maryland.

Ziccardi, L.M., Edgington, A., Hentz, K., Kulacki, K.J. and Driscoll, K. (2016) Microplastics as vectors for bioaccumulation of hydrophobic organic chemicals in the marine environment: A state-of-the-science review. *Environmental Toxicology Chemistry* 35 (7): 1667–1676.

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Appendix 1 - Fish attraction plan checklist

Item	Completed	Comments
Baseline habitat survey		Identify where existing fish habitat is located in the impoundment
Baseline fish survey		Understand the baseline fish distribution and key aggregation areas
Clear project objectives		Establish clear project objectives
Dam hydrology		Understand how water level changes will impact fish attractor placement
Stakeholder input		Identify and engage with key stakeholders about the proposed project and include their input
Waterway operator input and restrictions		Determine the waterway operator’s restrictions for fish attractor installation
Approvals and permits		Identify the necessary permits and approvals to obtain
Budget		Determine the level of funding required to construct and deploy fish attractors
Selection of suitable fish attractors		Identify fish attractors that are suited to the conditions and species of fish in the impoundment
Quantity of fish attractors needed		Determine the numbers for each type of fish attractor and check they are within the budget and will meet the project objectives
Fish attractor locations		Suitable sites for fish attractors have been identified away from strong currents, soft sediment and navigational routes
Deployment plan		A clear plan has been developed on when and how the fish attractors will be installed
Marking fish attractor locations		Decide the locations of signs or marker buoys to indicate where the fish attractors will be
Extension		How will information on the number, type and location of fish attractors installed be made publicly available?

Monitoring and evaluation		Develop a monitoring program to determine if the project goals are met
Review		Establish review process

Appendix 2 - Fish attractor suitability for stocked Australian native fish species

Table 2 *Suitability of fish attractor designs for commonly stocked Australian fish species. Ratings range from poor (★) to excellent (★★★★★).*

Species	Australian bass	Golden perch	Murray cod	Mary river cod	Silver perch	Sleepy cod	Barramundi	Saratoga
Brush piles	★★★	★★★	★★★	★★★	★★★	★★★★	★★★★	★★★★
Tree tops	★★★	★★★★	★★★	★★★	★★★	★★★★	★★★★	★★★★
Crappie condo	★★★★	★★★	★★	★★	★★	★★★	★★★	★★★
Whole trees	★★★★★	★★★★★	★★★★★	★★★★★	★★★	★★★★	★★★★★	★★★★
Porcupine crib	★★★★★	★★★★	★★★★	★★★★	★★★	★★★★	★★★★	★★★
Fish hotel	★★★★	★★★★	★★★★	★★★★	★★	★★★★	★★★★★	★★★
Spider	★★	★★★	★★	★★	★★★	★★★★	★★★	★★
Synthetic tree	★★★★	★★★★	★★★★	★★★★	★★★	★★★	★★★★	★★★★
Georgia cube	★★★	★★★★	★★★★	★★★★	★★★	★★★★	★★★★	★★★
Shelbyville cube	★★★★	★★★★★	★★★★	★★★★	★★★	★★★★	★★★★★	★★★★
Kinchant crib	★★★★	★★★★	★★★★	★★★★	★★★	★★★★	★★★★★	★★★★
Suspended FAS	★★★★★	★★★★	★★	★★	★	★★	★★★★	★★★
Commercial FAS	★★★	★★★★	★★★	★★★	★★★	★★★★	★★★★	★★★
Rock mounds	★★★★	★★★★	★★★★	★★★★	★★★	★★★★★	★★★★	★★★
Rock reefs	★★★★	★★★★	★★★★	★★★★	★★★	★★★★★	★★★★	★★★
Rock groins	★★★★	★★★★	★★★	★★★	★★★	★★★★★	★★★★	★★★
Reef balls	★★★	★★★★	★★★★	★★★★	★★★	★★★★★	★★★★	★★

Appendix 3 - Fish attraction plan example: Kinchant Dam

Kinchant Dam Fish Attraction Plan 2018-20

April 2018

This publication has been compiled by Andrew Norris of Agri-Science Queensland, Department of Agriculture and Fisheries.

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Background

Recreational angling in impoundments is increasing in popularity and generating significant social and economic benefits to regional communities. One of the major limiting factors on the success of an impoundment fishery is the lack of quality fish habitat. Dams with good quality fishing have substantial, high quality fish habitat in common. Since the majority of impoundments are not built or operated with fisheries as a major consideration, structural habitat suitable for fish is often lacking. Additionally, as impoundments age the remnant habitat degrades over time. Structural habitat is vital to support strong fish communities and angling opportunities.

Strategic installation of fish habitat structures in freshwater impoundments overseas has been found to be capable of significantly improving productivity, carrying capacity, growth rates, spawning and survival of wild and stocked fish (reviewed in Miranda 2016). The installation of habitat to attract fish also helps manage conflicts between waterway user groups and improve fishing for shore-bound or mobility limited anglers.

There is convincing evidence from the USA that strategic habitat enhancement has positively influenced their impoundment fisheries (reviewed in Norris 2016). Habitat enhancement has become a primary tool for fisheries managers in the USA and is used by almost all state fisheries agencies (Tugend *et al.* 2002, Norris 2016). The recreational fishery in many USA dams has been significantly improved, or even completely revitalised through the strategic use of fish habitat enhancement. This has led to significant increases in the number of angling tourists visiting or utilizing these impoundments and resulted in flow-on socio-economic benefits to local communities. These enhancement techniques have yet to be examined for Australian fish species under local environmental conditions.

To date, impoundment fisheries management in Australia has focussed on stocking and bag limits. There has been surprisingly little research or attention on impoundment fish habitat. The introduction of structural habitat for fish has been successfully used in open river systems to support native fish populations and led to localised increases in the abundance of fish species targeted by anglers. Much of this effort has focussed on providing the necessary resources required at various life history stages for fish to enable self-sustaining populations. Most of the impoundment fisheries in Queensland are put-grow-take and thus sustained by stocking. Many native fish species will not spawn in impounded waters. The focus of habitat installation in these impoundments is therefore on providing habitat to aggregate fish to improve the angling experience. A secondary benefit may be to improve survival of stocked fish where juvenile habitat is limited or of poor quality.

Kinchant Dam, located near Mackay, has been stocked with significant numbers of fish through the ongoing efforts of the Mackay Area Fish Stocking Association (MAFSA) and the Stocked Impoundment Permit Scheme (SIPS). The stocking efforts have resulted in healthy numbers of fish for anglers to target, particularly barramundi, but the dam is regarded by some as difficult to fish at times because accessible structure is limited to marginal vegetation. Some good structural fish habitat exists around the dam infrastructure (especially the dam wall), but these areas are closed to angling for safety reasons. Kinchant Dam therefore has the potential to benefit from the strategic introduction of fish habitat structures, and also provides an ideal setting to investigate the relative effectiveness of different fish attractor types.

Historically the materials used for fish attracting structures have largely been those that are convenient, economic and readily available (Miranda 2016). As knowledge in the field grows, more specialist fish attracting structures are being created to service specific needs of different species and size classes. Generally a combination of fish attracting structure types is utilized to provide greater diversity of habitats for a wide range of species. Many of the techniques are suitable for construction and deployment by community groups such as angling clubs, and can be cost-effectively implemented.

Objectives

The three main goals of this Fish Attraction Plan (FAP) are:

i) to improve recreational angling in Kinchant Dam by strategically installing fish attracting structures (FAS),

ii) encourage anglers to fish away from closed access areas near dam infrastructure

iii) to provide a platform for evaluating the response of native recreationally important fish species to different FAS types.

In areas with little habitat, fish are often dispersed and thus more difficult for anglers to locate and target. In Kinchant Dam many of the fish are located within the dense vegetation extending out from the shoreline and thus can be difficult to target. The installation of FAS can aid recreational anglers by aggregating fish into specific areas more suitable to different angling techniques, thereby increasing the probability that anglers cast their lure or bait in the vicinity or their target species. Fish attracting structures can attract prey species seeking food and refuge, provide refuge for stocked juvenile fish, and provide structure and ambush opportunities for predatory species (Miranda 2016).

Little research has been conducted on the response of Australian fish species to introduced structures in impoundments. This FAP forms part of a scientific project looking to determine the most effective type, location, density and deployment patterns for attracting fish to installed structures in Australian impoundments. A range of different FAS types will be installed and ideally monitored over several years. This information is essential for assessing the cost-benefit ratios for different FAS as well as the overall use of FAS.

Kinchant Dam

Kinchant Dam is located on the north branch Sandy Creek in the Pioneer Valley, 41km west of Mackay. The dam is managed by Sunwater and was built as the sole source of water for the Eton Water Supply Scheme. The catchment of Kinchant Dam is extremely small (30.84 km^2), mostly formed by the lake area itself and a small section of the north branch of Sandy Creek (Sunwater 2017). The dam instead relies on water pumped from the Pioneer River via the Mirani Diversion Channel which is supplied by three water harvesting pump stations located at Mirani Weir. Construction of the dam occurred in stages, commencing in 1974 and was completed in 1986. A 5.325 km long, earth and rock-fill embankment up to 22.3 m high was built to create the dam and contains an uncontrolled mass gravity ogee crest spillway (Sunwater 2017). The average depth of the dam is only 6.8 m, reaching a maximum of 14.9 m at full supply level. At full storage capacity (57.21m AHD) the dam holds 62,800 ML and covers 920 ha. The water release off-take occurs twin 1.35 m diameter pipes housed in a tower off the western end of the dam wall.

Although constructed for irrigation water supply, Kinchant Dam is now also used for a range of recreational activities. A private campground is located on the shores of the lake to the south of the day use areas and boat ramp. With no crocodiles present, fishing, boating, kayaking, paddle boarding, canoeing, swimming and sailing are all permitted and prevalent on the dam. The dam is also very popular for faster water based activities such as water skiing, wake boarding and PWC riding.

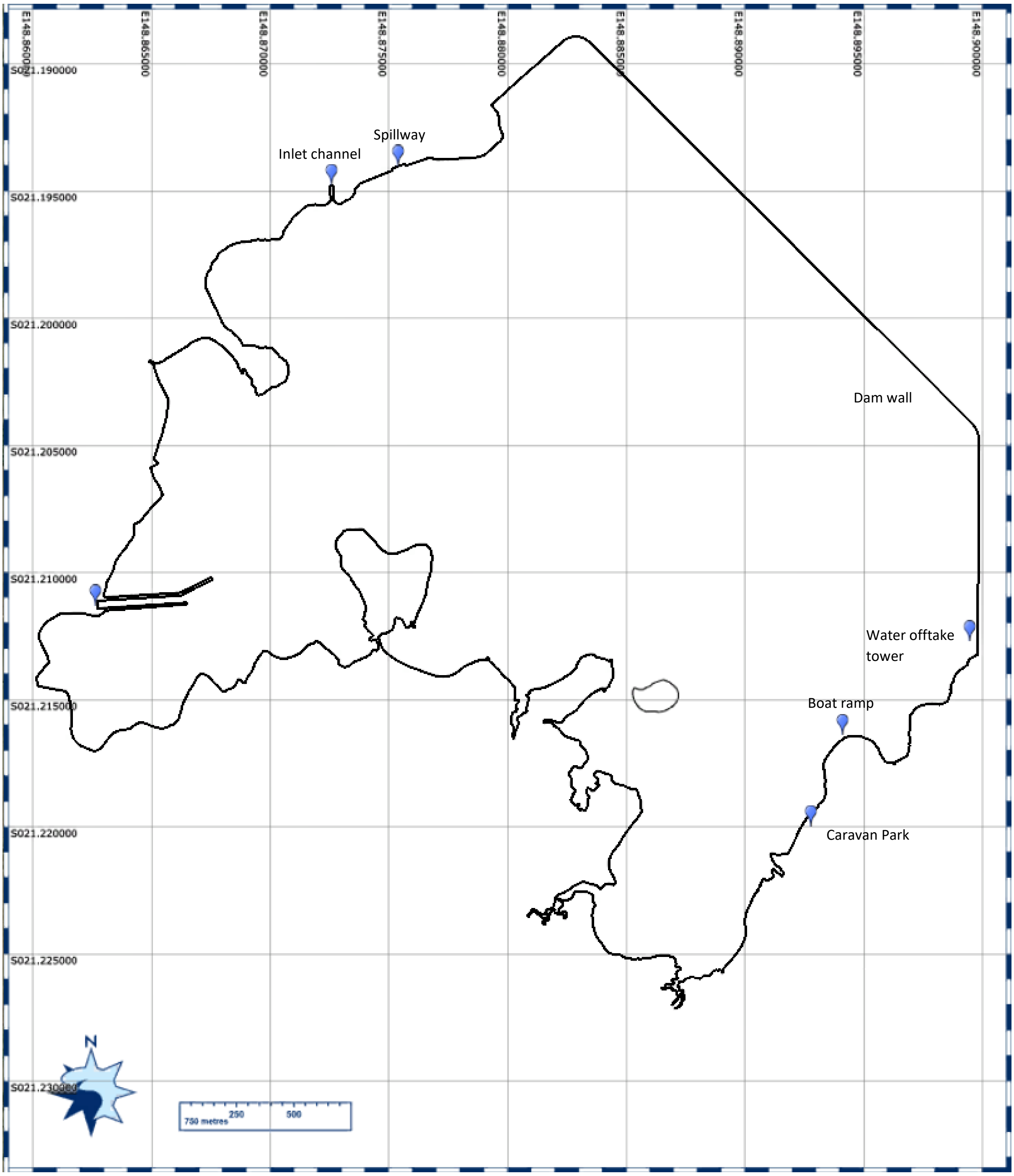


Figure 1. Outline map of Kinchant Dam indicating main infrastructure locations.

Existing structure and fish habitat

To aid development of the FAP, a sonar survey was conducted by DAF in February 2018 across Kinchant Dam to map the bathymetry and existing fish habitat (Figures 2-3). The survey confirmed that there was limited structural complexity in the dam (apart from extensive marginal vegetation), that would be likely to aggregate fish and highlighted the need for the introduction of FAS. The sonar survey detected a strong thermocline located between 4.5-6 m depth across most of the dam.

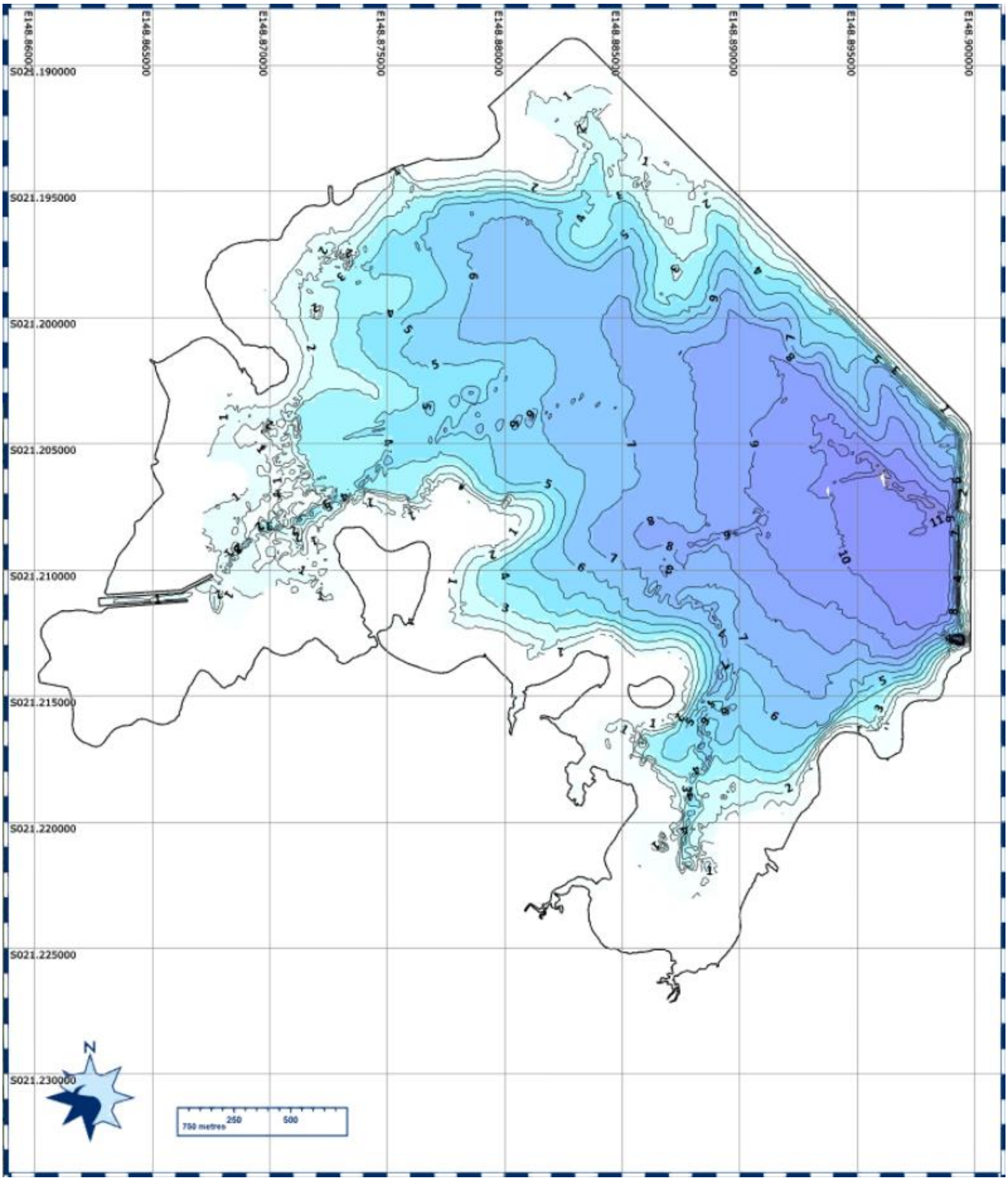


Figure 2. A bathymetric map of Kinchant Dam from the February 2018 survey. Depth contours were generated at a dam supply level of 54.09 m AHD.

The dam's habitat was dominated by silty flats with extensive vegetation around the shoreline. Three channel complexes were also identified, which contained firmer substrate and some small drop-offs. The dam's rock wall was the dominant structure identified likely to attract fish and contained the vast majority of hard structure present. This extensive wall provides rocky habitat around approximately 40 % of the dam's shoreline on the northern side and in areas has created steep gradients and drop-offs into deep water. A 100 m exclusion zone exists along the wall for navigational safety, so this area is not accessible to anglers. The toe of the dam wall extends to the edge of the exclusion zone, where the rocks form a distinct boundary line with the adjacent softer substrate. The shoreline on the southern side of the dam typically had mild gradients and more extensive aquatic vegetation.

Marginal submerged and floating macrophyte growth was dense to around 2.5 metres depth around much of the dam shoreline, with more scattered clumps occasionally extending to 5 metres depth in parts. The deeper margins of the dense vegetation often formed well defined edges; however in a few locations, short, new growth extending from the vegetation beds was observed. Several simple tree trunks and logs were present in the vicinity of both major channels (Figure 3) and adjacent to the boat ramp and day use areas. However these logs lacked structural complexity (no branching or apparent root balls) and are likely to offer little habitat for most fish species. Only a single emergent standing tree was observed in the south west of the dam. This tree was surrounded by the remnant stumps from an old building and was in a zone containing dense growth of aquatic vegetation. As such, at the low water levels observed during the survey it is unlikely to provide much cover for fish.

A submerged road was detected in the eastern part of the dam (Figure 3). The road typically provided little vertical relief (< 1 m) from the surrounding substrate, but was clearly evident as a harder bottom. The main hard substrate features in the dam apart from the dam wall were the channels (Figure 3). The remnant of the north branch of Sandy Creek reached from the Abington Pump Station towards the centre of the dam. The channel was well defined in shallower areas, but became undetectable in the middle of the dam beyond 7 m depth. The most pronounced channel occurred in the south eastern section of the dam. A winding and clearly incised channel, extended from the large gully in the south east corner, all the way to near the dam wall. The meandering channel was incised up to 2 m deep in places and contained several rock ledges on the outside of bends. Similar to the remnant channel from the north branch of Sandy Creek, the eastern channel became less pronounced in the middle of the dam in 9 – 10 m of water. Closer to the dam wall, the channel became more defined again and contained the deepest section of the dam.

A deep basin of water approximately 40 m in diameter was located adjacent to the water offtake tower in the eastern corner of the dam. The maximum depth here was slightly less (1.2 m less) than the channel further to the north along the dam wall. The infrastructure for the water offtake tower created significant vertical relief and structural complexity and would prove highly attractive to many fish species.

The other piece of dam infrastructure likely to influence fish distributions in the dam is the inlet channel. When operating, significant volumes of water enter the dam through the channel, creating a strong current and scoured substrate. A small, well defined rock ledge has formed on the southern side of the channel where the incoming water enters the dam. The substrate surrounding the inlet channel consists of a clay, mud and gravel composition and aquatic vegetation growth is mostly scattered in the area.

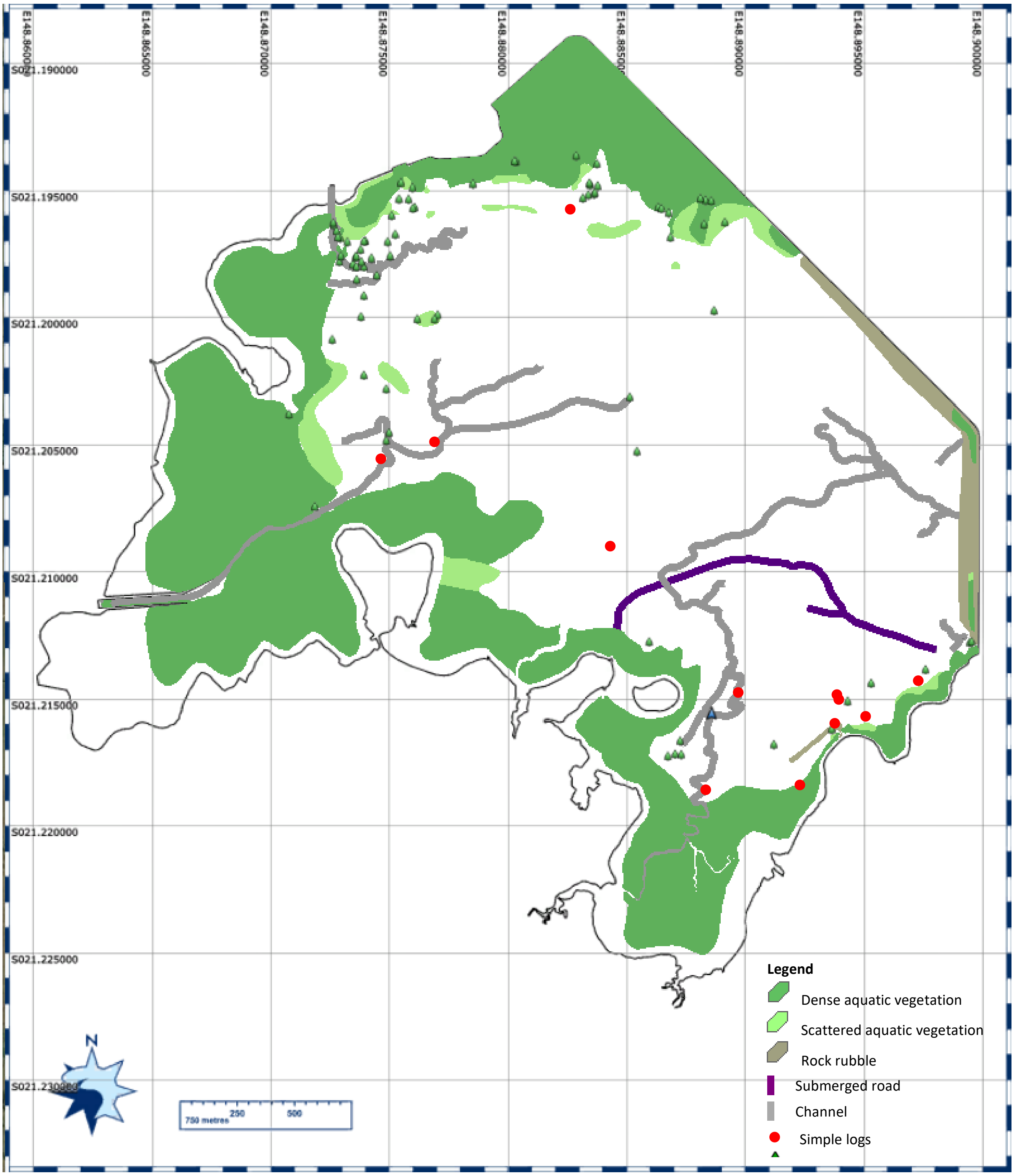


Figure 3. The pre-existing fish habitat Kinchant Dam

Fish distribution

Kinchant Dam is stocked by the MAFSA under the SIPS. The dam was originally stocked with sooty grunter (*Hephaestus fuliginosus*) and sleepy cod (*Oxyeleotris lineolata*) for recreational angling, but since 2000, barramundi (*Lates calcarifer*) have also been released (Keiron Gallety, MAFSA personal communication). The dam also contains self-sustaining populations of fork-tail catfish (*Arius graeffei*), eel-tailed catfish (*Tandanus tandanus*) and spangled perch (*Leiopotheropon unicolor*). Bony bream (*Nematalosa erebi*) are highly abundant and the dominant prey species. Other native fish observed include fly-specked hardyhead (*Craterocephalus stercusmuscarum*) and mouth-almighty (*Glossamia aprion*) and snub-nosed garfish (*Arrhamphus sclerolepis*). Barred grunter (*Amniataba percoides*) have also become highly abundant in shallow waters of the dam.

Barramundi and sooty grunter are the primary targets for most recreational anglers. These two species both display a strong preference for structure (Allen *et al.* 2003). In Kinchant Dam both of these species are primarily found in the vicinity of the extensive beds of aquatic vegetation. This vegetation provides both food resources and structure from which to ambush prey. Barramundi are also found in the open waters at times, hovering near the thermocline beneath schools of bony bream. In the cooler period of the year, barramundi are often found tight in amongst the vegetation on the leeward shore of the dam where the warmer surface water is pushed by the wind (Grech 2009). Barramundi and sooty grunter are both attracted to flowing waters at times, and one of the aggregation points in Kinchant Dam is the inlet channel when water is being pumped into the dam from the Pioneer River.

A total of 212 barramundi, 17 sleepy cod and 10 sooty grunter were captured during the electrofishing survey of 40 sites within Kinchant Dam in February 2018. The barramundi ranged between 221 mm and 1000 mm in total length (Figure 6), but the majority were large (mean = 860 mm TL). The sleepy cod were all quite small, ranging from 80-279 mm. All of the sooty grunter captured during the survey were large (420-445 mm FL), and all but one were captured from the fast-flowing water coming in from the inlet channel. No sooty grunter and very few barramundi were captured from open water sites away from vegetation of inflowing water.

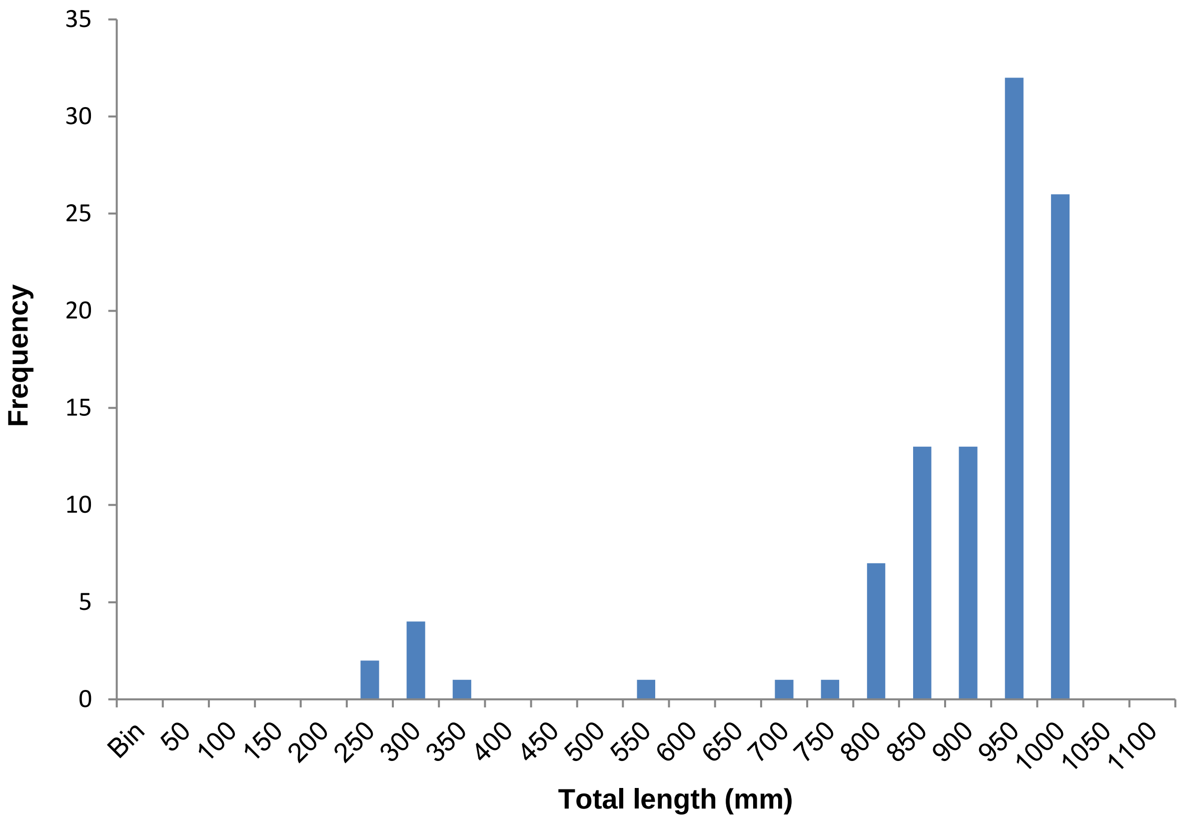


Figure 4. The length-frequency distribution of barramundi captured during the electrofishing survey in February 2018.

Dam hydrology

Data from Sunwater for the last decade indicates Kinchant Dam typically has had relatively high supply levels over during that period (Figure 5). The dam's lowest storage level was 52.37 m in February 2016, which still equated to approximately 44% of full storage capacity. Supply levels in the dam typically fluctuate periodically, reaching their lowest levels between November and January and maintaining highest levels between March and September when irrigation demand is at its highest (Figure 5). Most years small and brief overtopping events occur at the spillway when high rainfall occurs late in the wet season.

Although water levels in Kinchant Dam can fluctuate up to 5 m, they are typically high for much of the time. The mean supply level over the last decade has been 56.40 m AHD, only 0.81 m below full capacity. Median and the 50th percentile of supply levels were both 56.95 m AHD, whilst the mode was 57.19 m AHD, only 0.02 m below full supply. The 75th percentile of water level heights in the dam was 55.83 m AHD, 1.38 m below full supply level. The 90th percentile of water level heights in the dam was 54.90 m AHD, 2.31 m below full supply (Figure 5). At this level any FAS located beneath the surface should remain submerged for 90% of the time and thus this depth will be used for planning the locations of FAS.

During the sonar and fish surveys of the dam in late February 2018, the supply level was only 54.09 m AHD or approximately 60% storage capacity. Unfortunately water levels this low have only occurred four times in the last decade. Some areas of the dam were inaccessible to be surveyed by boat. Additional data collection will occur in these areas during June when water levels are likely to be higher.

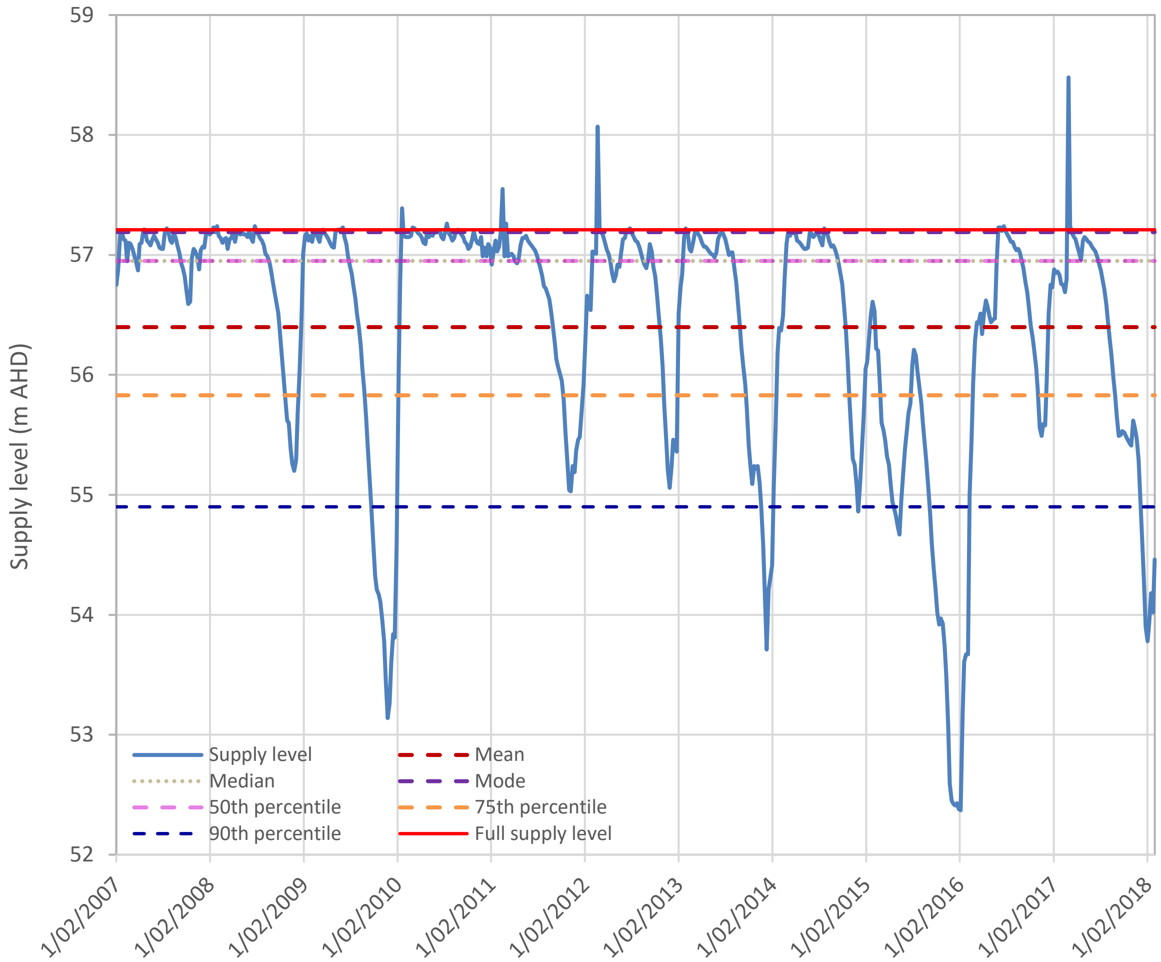


Figure 5. Supply water levels in Kinchant Dam between 2007 and 2018. Data provided by Sunwater.

There is very limited flow within Kinchant Dam because the catchment is so small. The highest flow velocities occur near the inlet channel which produces a strong inflow when operating. This flow is directed away from the wall, towards the middle of the dam. The lack of flow elsewhere in the dam means there is little risk of FAS shifting due to water currents and therefore flow and currents do not limit where habitat can be situated.

Stakeholder consultation

A broad range of stakeholders have been consulted during the preparation of this fish attraction plan. The primary stakeholders for Kinchant Dam include Mackay Regional Council (co-investors), Sunwater (waterway operator), Mackay Area Fish Stocking Association (local fish stocking group), Mackay Recreational Fishing Alliance (MRFA) and the Department of Agriculture and Fisheries (manage stocking, SIPS and research). A community forum was held in February 2018 to discuss the project and was attended by the above stakeholders plus a local charter fisherman, a representative from St Patricks College, a local tackle shop and one of the local Men's Shed groups. Additional organisations who have been contacted since the meeting include Rotary groups and the Mackay Christian College. Although water-skiing, wake-boarding and riding PWC are popular on the dam there are no representative organisations for these activities with which we could directly engage.

Fish attraction structures (FAS)

Types

A number of different FAS types will be used in Kinchant Dam. The selection of FAS will provide diverse structural complexity and be suitable to be employed at different depths. All materials used to construct the FAS will be organic or inert to ensure there are no detrimental impacts on the aquatic environment. The majority of recommended FAS types are relatively snag-free, meaning anglers can fish right in amongst the habitat with less fear of losing gear. Brush bundles are the exception, but they are relatively cheap and provide excellent structural complexity. All FAS will be suitably weighted and located to ensure that movement from flow or tampering is minimal. Water skiing, wakeboarding and riding PWCs is extremely popular at Kinchant Dam so all FAS will be designed to minimise impact or injury if struck by a boat or towed person. The more solid porcupine cribs and Georgia cubes will only be deployed in deeper water where the water remains sufficiently deep to avoid collision even at lower water levels.

FAS types will include:

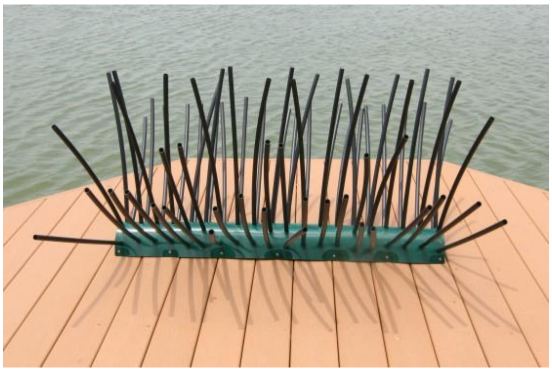
1. Brush and timber
    - Brush bundles


    - Porcupine fish cribs
        - Made from timber or synthetic pipes

2. Synthetic materials

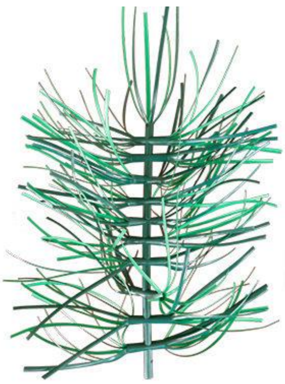
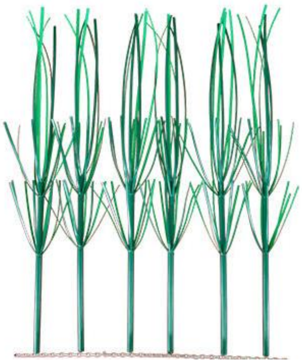
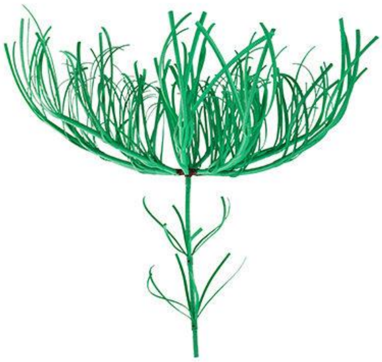
- Georgia cubes


- Synthetic hedges

- Synthetic plants and trees



3. Suspended or floating

- Similar to synthetic trees, but suspended 1 - 5 m below the surface
- For deeper water use only.

Locations

It is proposed that a total of 194 FAS be installed into Kinchant Dam, consisting of 88 synthetic trees, 36 brush bundles, 30 synthetic hedges, 23 Georgia cubes, 14 porcupine cribs and 3 suspended FAS. The FAS will be located around the margins of the dam at 36 locations (Figure 5). This will disperse angler effort and provide accessible habitat for fish throughout the year. All FAS will be readily accessible to boat anglers the majority of the time and are located outside of restricted access zones (Figure 7). No FAS will be placed in the middle of the dam to minimise interactions between anglers and skiers, and to minimise potential collisions. Additionally, FAS will be placed sufficiently deep so as to remain fully submerged when water levels remain above 54.9 m AHD (the 90th percentile for supply level). There is also a risk FAS placed in shallow water will become overgrown by aquatic vegetation, and rendered of limited value. Therefore, no FAS will be placed in water shallow than 3 m, based on the 90th percentile for water levels. The FAS will also be placed beyond the aquatic vegetation margins observed in February 2018, when water levels were at only 54.09 m AHD (below the 90th percentile level). This will again minimise the risk of them becoming overgrown.

Where possible, the locations of FAS have been selected to enhance the structural complexity of existing habitat, particularly remnant creek channels and the edges of aquatic vegetation beds. Where no existing habitat is present, the FAS will be used to create new fishing hotspots. Flow rates in the dam are very low so there is little risk of structures drifting. Thus several FAS sites are contained within or adjacent to the remnant creek channels. This area has the potential to develop into a premier trolling run. The closed zone adjacent to the dam wall provides complex fish habitat, but cannot be accessed by anglers. Four FAS sites will be established in the deep water outside of the closed zone to attract fish and hold fish from the nearby rock and rubble. These sites have potential for deep trolling runs or vertical jigging upon the installed structures.

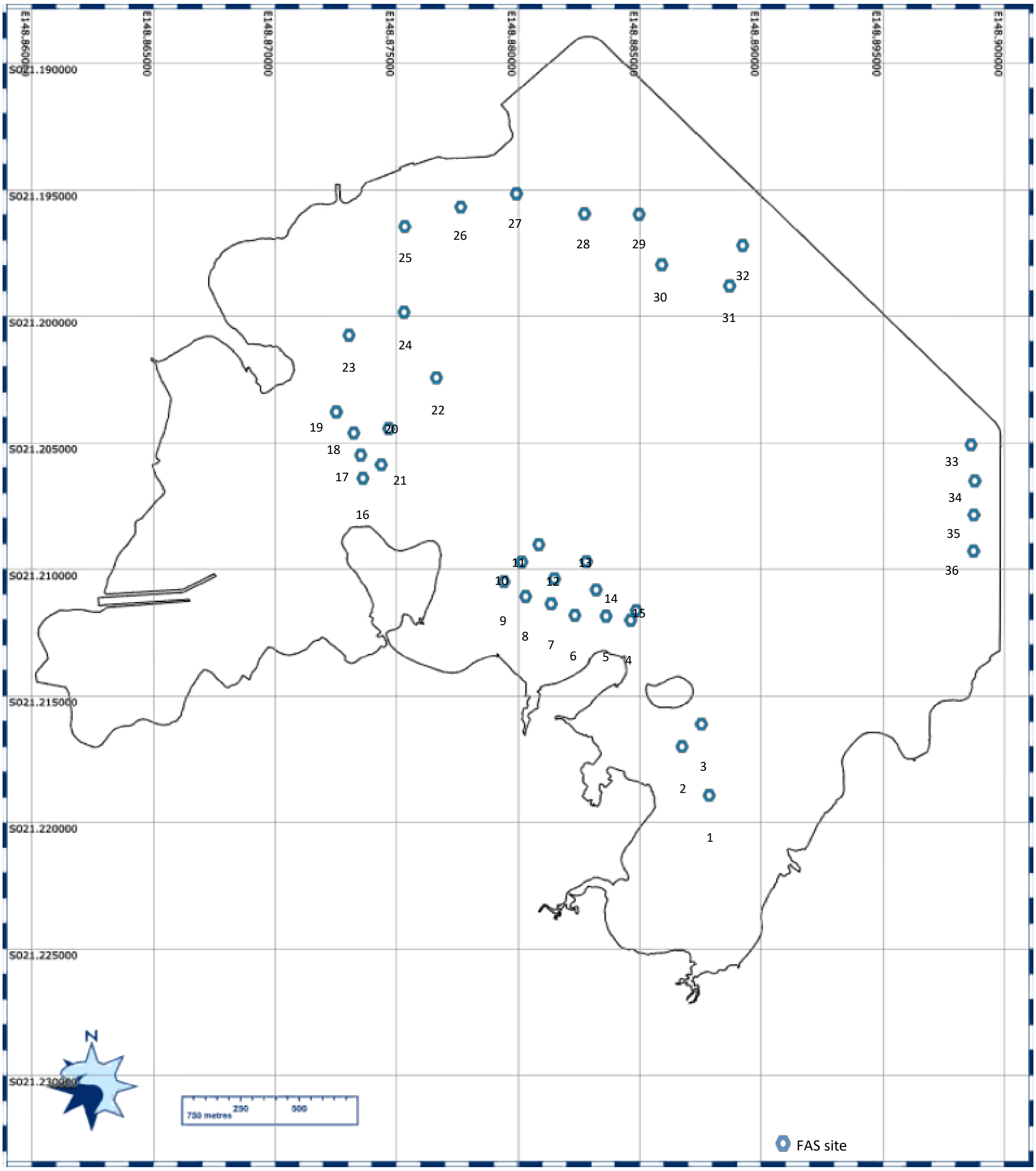


Figure 6. The location of proposed fish attracting structure (FAS) sites around Kinchant Dam. Refer to Table 1 for the type of FAS at each site.

In addition to the deep water habitat sites along the dam wall, three suspended FAS sites will also be trialled (FAS 30-32, Table 1). These FAS will be located around a deep water spit and drop-off. A surface buoy will be used to mark the location of each site as well as suspend the FAS. Several large structures will also be deployed on the bottom around the float's mooring to provide additional structural complexity.

At each site, a cluster of FAS will be used to create habitat complexity. The FAS will typically be deployed in an open circle or cross pattern. These designs create gaps between the structures for fish to move through and have been reported to be the most utilized designs in the USA (Miranda 2017).

Table 3. The location of proposed fish attracting structure (FAS) sites around Kinchant Dam.

Name	Latitude	Longitude	FAS types
FAS 1	-21.218939	148.887878	Synthetic trees
FAS 2	-21.217009	148.886765	Georgia cubes and brush
FAS 3	-21.216127	148.887558	Synthetic trees
FAS 4	-21.212023	148.884644	Synthetic hedge, brush and synthetic trees
FAS 5	-21.211864	148.883636	Synthetic hedge, brush and synthetic trees
FAS 6	-21.211830	148.882355	Synthetic hedge, brush and synthetic trees
FAS 7	-21.211372	148.881378	Synthetic hedge, brush and synthetic trees
FAS 8	-21.211084	148.880325	Synthetic hedge, brush and synthetic trees
FAS 9	-21.210499	148.879440	Synthetic hedge, brush and synthetic trees
FAS 10	-21.209721	148.880173	Synthetic hedge, brush and synthetic trees
FAS 11	-21.209038	148.880875	Synthetic hedge, brush and synthetic trees
FAS 12	-21.210388	148.881516	Brush and synthetic trees
FAS 13	-21.209705	148.882828	Georgia cubes and synthetic trees
FAS 14	-21.210825	148.883224	Georgia cubes and synthetic trees
FAS 15	-21.211639	148.884872	Georgia cubes and synthetic trees
FAS 16	-21.206415	148.873642	Synthetic hedge and brush
FAS 17	-21.205500	148.873550	Synthetic trees
FAS 18	-21.204626	148.873260	Brush
FAS 19	-21.203793	148.872543	Synthetic trees
FAS 20	-21.204453	148.874695	Brush and synthetic trees
FAS 21	-21.205881	148.874390	Synthetic trees
FAS 22	-21.202446	148.876663	Georgia cubes and synthetic trees
FAS 23	-21.200766	148.873062	Synthetic hedge and brush
FAS 24	-21.199858	148.875336	Synthetic trees
FAS 25	-21.196470	148.875366	Brush
FAS 26	-21.195703	148.877660	Porcupine crib and synthetic trees
FAS 27	-21.195177	148.879952	Synthetic trees
FAS 28	-21.195971	148.882751	Georgia cubes and brush
FAS 29	-21.197658	148.883269	Synthetic trees
FAS 30	-21.197979	148.885925	Suspended and Georgia cubes
FAS 31	-21.198818	148.888718	Suspended and porcupine cribs
FAS 32	-21.197214	148.889252	Suspended and synthetic trees
FAS 33	-21.205090	148.898651	Porcupine cribs and Georgia cube
FAS 34	-21.206516	148.898804	Porcupine cribs and synthetic trees
FAS 35	-21.207863	148.898773	Porcupine cribs, Georgia cube and synthetic trees
FAS 36	-21.209290	148.898758	Georgia cube and synthetic trees

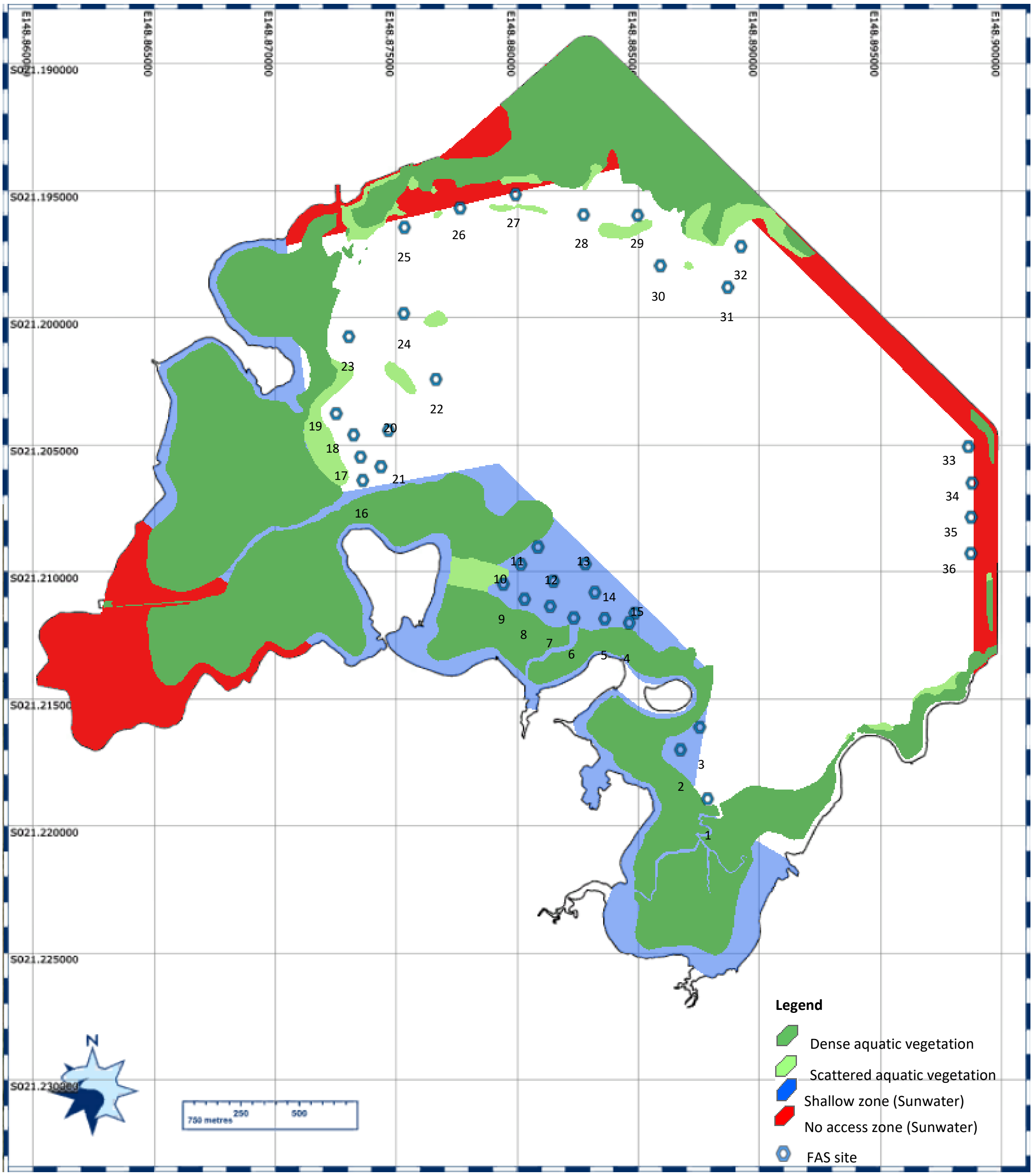


Figure 7. *The location of proposed fish attracting structure (FAS) sites around Kinchant Dam relative to Sunwater dam management zones and aquatic vegetation.*

Detailed descriptions, maps and GPS coordinates for each of the FAS deployment areas can be found in Appendix 1 (Figures 9-41, Tables 3-38).

Details of the type and location of all FAS will be made available to the general public via:

- Labelled floats for suspended deep water FAS
- An information sign containing a map and coordinates at the boat ramp
- An online PDF map
- Access to downloadable Google Earth map files

Monitoring and evaluation

A multi-faceted approach using electrofishing and competition angling catch data will be used to monitor the response of fish and angler catch in Kinchant Dam. During the baseline surveys, forty electrofishing monitoring sites were established across the dam (Table 2, Figure 8). These sites were typically located in or adjacent to aquatic vegetation beds, hard structure or creek channels around the dam. Several sites were located in deeper and more open water where FAS were likely to be installed. Once the FAP has been developed, additional monitoring sites in areas where FAS are to be installed may be needed.

Electrofishing provides an instantaneous sampling method to survey the fish assemblage and is the standard sampling technique used by freshwater fisheries research organisations in Australia, New Zealand, Europe, and the USA. Fish are stunned by pulsing an electric current through the water and netting the stunned fish. Electrofishing is typically limited to relatively shallow waters because the stunning range only extends up to 3-4 metres from the anodes. At each monitoring site, fish will be actively targeted by electrofishing for with a total power on time of 300 seconds per site. Our large boat with a 7.5 KVA generator will be used because it produces the broadest field and has the best capacity for stunning fish in deeper water. Electrofishing surveys will be conducted twice annually in summer and winter.

Table 4. Electrofishing monitoring sites in Kinchant Dam.

Name	Latitude	Longitude	Name	Latitude	Longitude
K1	-21.194340	148.879380	K21	-21.207410	148.872980
K2	-21.192820	148.883840	K22	-21.210350	148.871570
K3	-21.195740	148.888227	K23	-21.211160	148.865080
K4	-21.198840	148.893100	K24	-21.208220	148.867800
K5	-21.204670	148.898520	K25	-21.203760	148.868070
K6	-21.207970	148.898982	K26	-21.202570	148.871560
K7	-21.214340	148.897720	K27	-21.199310	148.870450
K8	-21.194340	148.879380	K28	-21.216499	148.888092
K9	-21.215960	148.895130	K29	-21.212840	148.888350
K10	-21.218430	148.892460	K30	-21.211340	148.881290
K11	-21.219380	148.889620	K31	-21.209710	148.884030
K12	-21.220530	148.887040	K32	-21.207530	148.881470
K13	-21.217830	148.885780	K33	-21.205960	148.877700
K14	-21.214820	148.887860	K34	-21.206290	148.875390
K15	-21.212960	148.885200	K35	-21.204410	148.872200
K16	-21.212830	148.882270	K36	-21.196079	148.874695
K17	-21.212080	148.879200	K37	-21.198180	148.887260
K18	-21.209800	148.878310	Inlet	-21.196290	148.872660
K19	-21.207160	148.878900	Spillway	-21.194170	148.875550
K20	-21.207270	148.876210	Offtake tower	-21.212660	148.899630

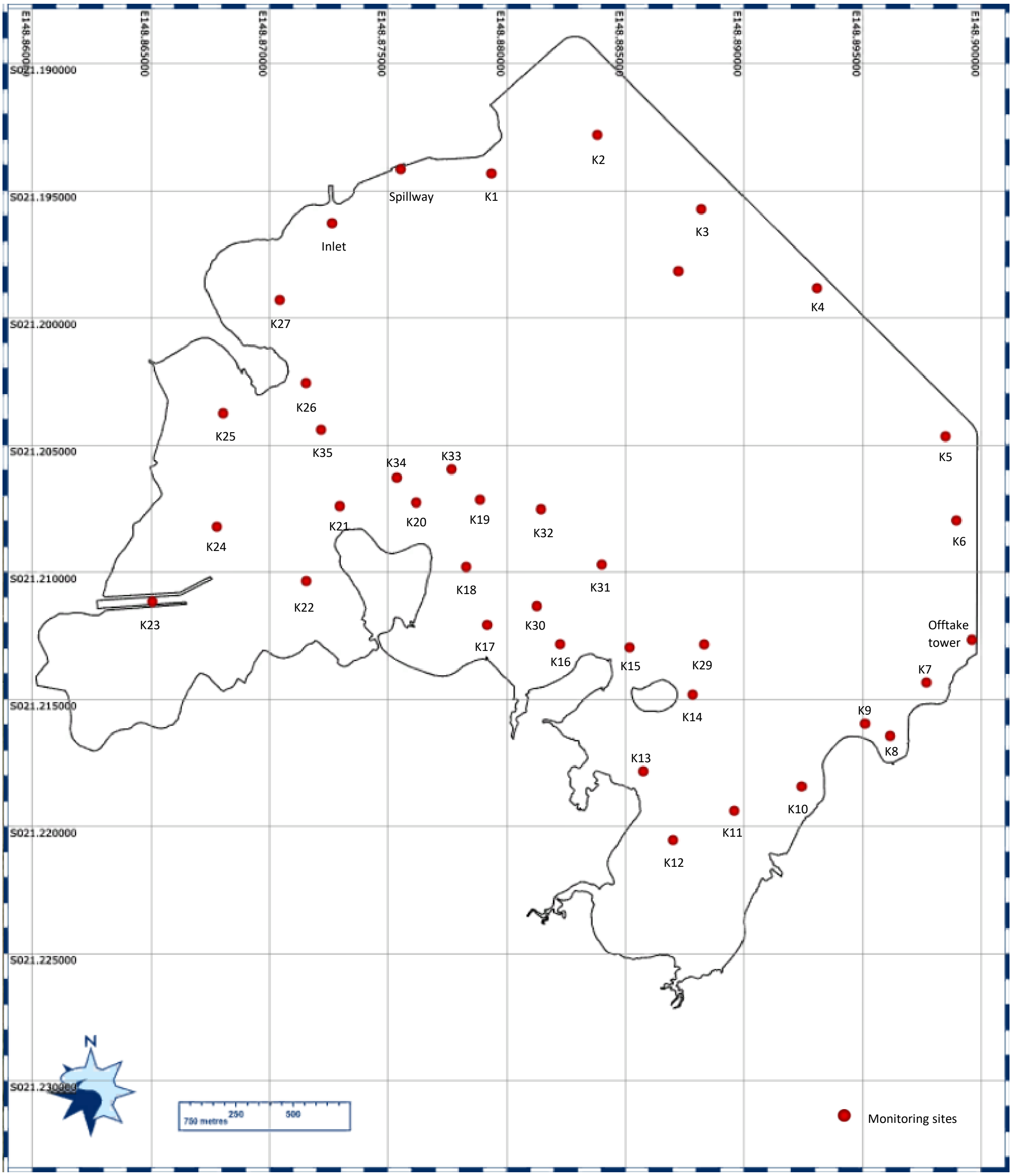


Figure 8. The location of electrofishing monitoring sites within Kinchant Dam.

Two fishing tournaments are held in Kinchant Dam each year in March and November. The data collected from these can help monitor the use of FAS by both anglers and fish and identify changes between pre and post installation of the FAS.

The quality and quantity of the FAS will be monitored via yearly sonar surveys and underwater video. This will assess the growth on the structures and physical integrity and degradation.

Risk assessment

Risk	Likelihood	Mitigation strategy
Damage of infrastructure by FAS	Low Flow rates within the dam are extremely low.	• Construct FAS with light-weight material and use an open structure to minimise resistance to flow • Ensure adequate weighting of bases to restrain movement. Where higher flow rates are anticipated, additional weight will be used • FAS will not be placed in the immediate vicinity of any infrastructure
FAS will be a navigation hazard	Low Most structures are not rigid and are unlikely to damage vessels. If water levels drop significantly some FAS may become more exposed, but navigation in these areas would be difficult regardless of their presence.	• The location of FAS will be displayed on a sign at the boat ramp and available online • FAS will be located mostly along the shorelines in suitably deep water, away from areas popular with water skiers and PWC riders • All FAS will be installed such that they remain completely submerged for >90% of fluctuations in supply level. • Most FAS will have light weight, flexible construction, so if contacted will bend or give • More solid FAS will only be used in deeper water and out of typical navigational routes • Suspended FAS will be marked by surface buoys and only deployed in deep water • Online access to the nature and location of FAS will be available.

Risk	Likelihood	Mitigation strategy
Contamination of water or the aquatic environment	Unlikely Materials used to construct the FAS have been selected because they are inert or organic (brush or timber) and not likely to degrade into harmful materials or release toxic leachates.	• Refer to Material Safety Data Sheets for any non-organic materials used (e.g. PVC and Drainage pipes) • Recycled materials which have been previously exposed to hazardous substances will not be used • All synthetic materials used to be UV stabilised • All timber used to be untreated • Species of plant used for brush and timber FAS will not be toxic (i.e. not oleander or tea trees) when submerged
Increased pressure on fish stocks	Unlikely. The fishery is a put and take fishery and intended for some angler harvest. Barramundi are the most frequently targeted and caught species and in impoundments most anglers practice catch and release. Thus excess harvest of this species is unlikely. Similarly sooty grunter are primarily treated as a catch and release species.	• Ensure adequate stocking is undertaken • Conduct periodic stock assessments • Ensure angler education is undertaken to minimise the impacts of catch and release fishing on fish welfare and survival • Structures may increase stocked fingerling survival

Review

The Kinchant Dam Fish Attraction Plan 2018-20 shall be reviewed annually (until 2020) by DAF in consultation with the other key stakeholders. The results of the monitoring and evaluation will be used to evaluate project progress, refine FAS designs, distributions and site parameters, and determine the most effective FAS type and locations for future deployment. The revised plan will then be circulated amongst stakeholders for feedback before being ratified.

Acknowledgments

This fish attraction plan forms part of a larger project to improve recreational fishing in Kinchant Dam and which is supported by funding from the Queensland Department of Agriculture and Fisheries and Mackay Regional Council. Details of the dam fishery and potential sites for fish attracting structures (FAS) were kindly contributed by Luke Galea (MRC), Kieron Galletly (MAFSA) and Richard Skeet (Sunwater) and their help has been greatly appreciated.

References

Allen, G.R., Midgley, S.H. and Allen, M. (2003) *Field guide to the freshwater fishes of Australia*. Western Australian Museum, Perth 394 pp.

Gregg, D. and Rolfe, J. (2013) *An economic assessment of the value of recreational angling at Queensland dams involved in the Stocked Impoundment Permit scheme*. Centre for Environmental Management, Central Queensland University, North Rockhampton. 47 pp.

Grech, D. (2009) Winter Kinchant topwater techniques. *Queensland Fishing Monthly,* May 2009

Kuhl, N.**,** Florence, M. and Mott, M. (2003) *QLD southern dams*. AFN fishing map 19, Australian Fishing Network, Croydon, Victoria

Miranda, L.E. (2017) *Reservoir fish habitat management*. Lightning Press, Totowa, New Jersey. 296 pp.

Norris, A. (2016) *Increasing Australian impoundment fisheries potential: Habitat enhancement to improve angling and productivity in impoundments*. Winston Churchill Fellowship Report, Winston Churchill Memorial Trust of Australia, Canberra.

Sunwater (2017) *Emergency action plan - Kinchant Dam*. Sunwater Limited, File 08-000370/001, Brisbane, Queensland. 177 pp.

Tugend, K.I., M.S. Allen, and Webb, M. (2002) Use of artificial habitat structures in U.S. lakes and reservoirs: a survey from the Southern Division, AFS Reservoir Committee. *Fisheries* 27(5):22–27.

Appendix 1 – Examples of FAS site maps and descriptions

FAS 1 – cluster in a deeper hole

Depth: 7.87 m at full supply level and 5.56 m at 90th percentile of water level

In creek channel, 20 m from dense vegetation margin

1 x round cluster of 5 synthetic trees

4 m between trees

Central coordinates = -21.218920, 148.887894

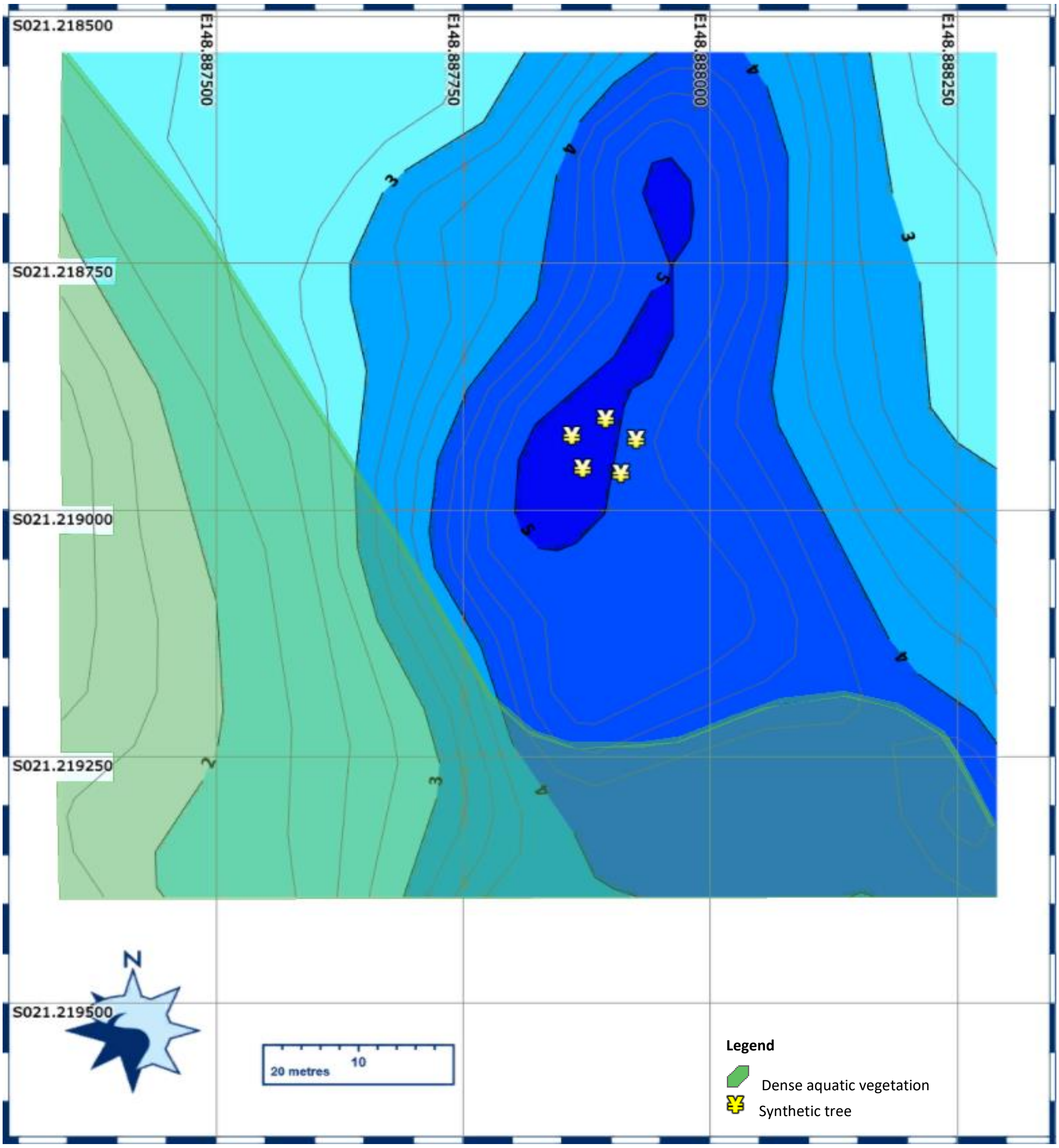


Figure 9. The location and deployment pattern of structures at FAS 1. Depth contours were generated at a dam supply level of 54.09 m AHD.

FAS 3 – cluster near a point

- Depth: 7.12 m at full supply level and 4.81 m at 90th percentile of water level
- Near moderately sloping bank, off small point
- 30 m from dense vegetation margin and channel
- 1 x cross shaped cluster of 5 synthetic trees
- 4 m between trees
- Central coordinates = -21.216109, 148.887532

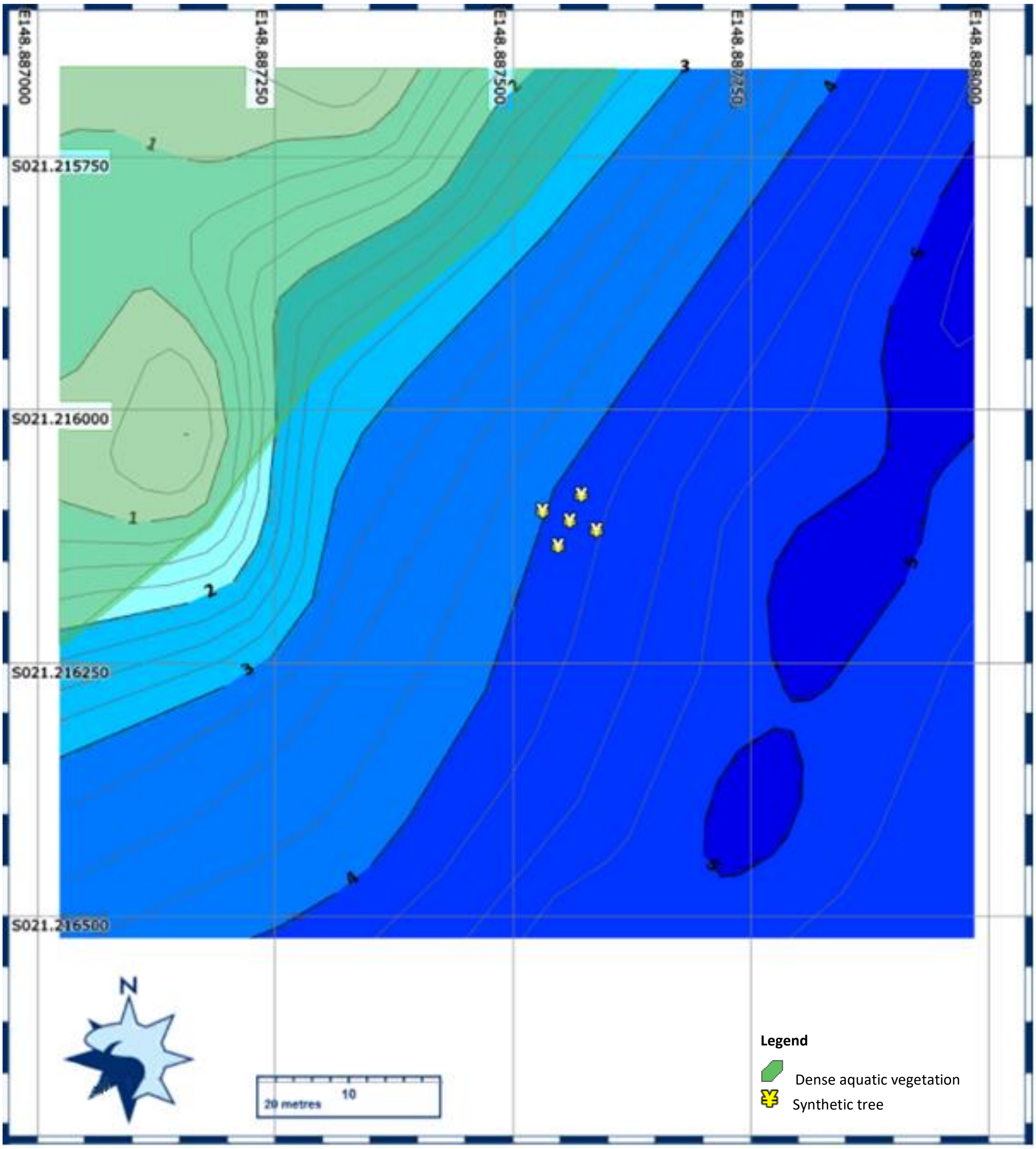


Figure 10. The location and deployment pattern of structures at FAS 3. Depth contours were generated at a dam supply level of 54.09 m AHD.

FAS 4 – perpendicular line to shore and vegetation

- Depth: 7.12 m at full supply level and 4.81 m at 90th percentile of water level
- On top of old road 15 m from dense vegetation
- 1 x cluster of 3 synthetic hedges, 1 brush pile and 1 synthetic tree in a line along the road
- 2 m between synthetic hedges and 3 m between brush pile and synthetic tree
- Central coordinates = - 21.212052, 148.884644

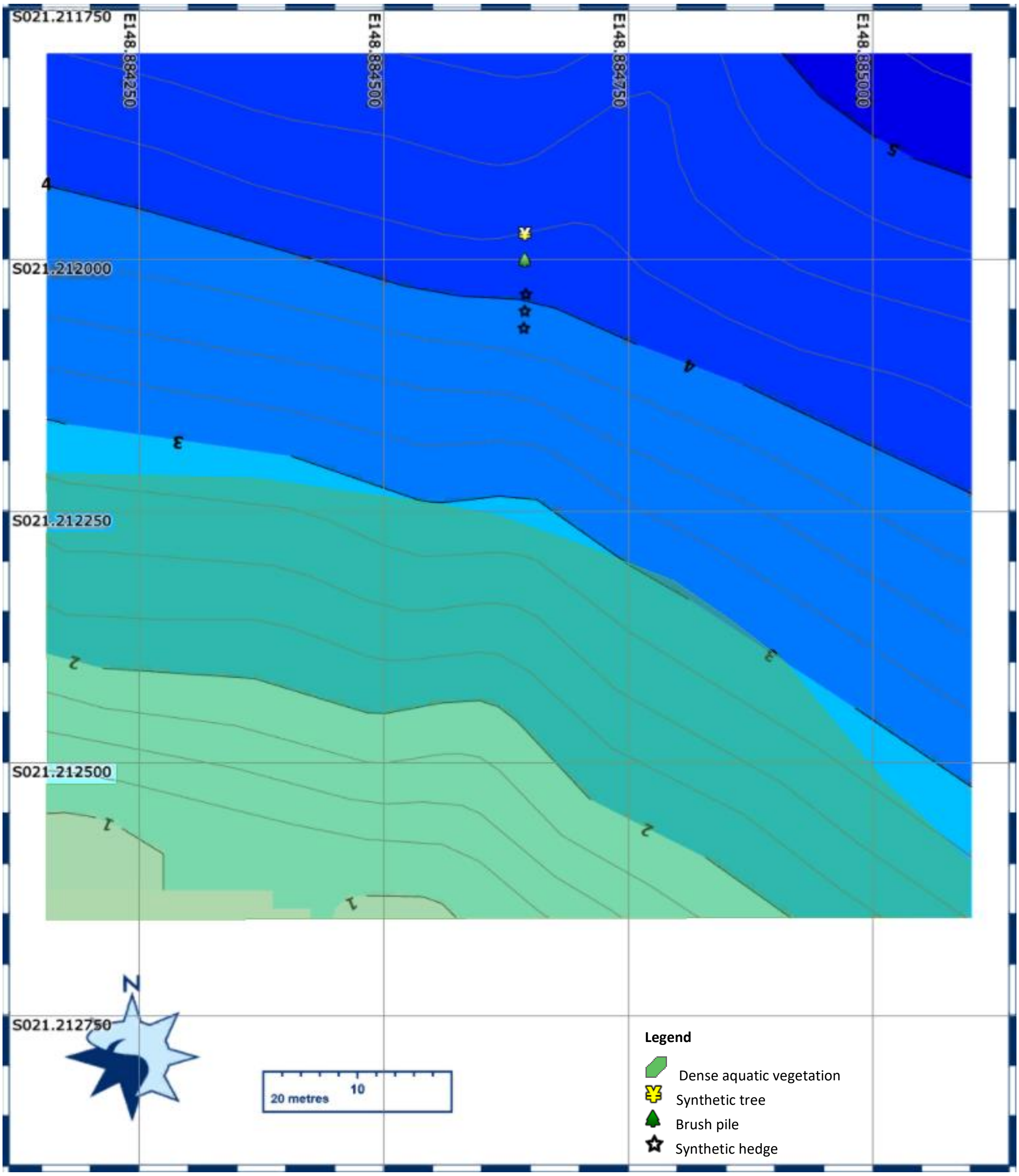


Figure 11. The location and deployment pattern of structures at FAS 4. Depth contours were generated at a dam supply level of 54.09 m AHD.

FAS 15 – on a point

- Depth: 8.37 m at full supply level and 6.06 m at 90th percentile of water level
- On top of old submerged road
- 1 x circular shaped cluster of 4 synthetic trees and 3 Georgia cubes
- 3 m radius between structures
- Central coordinates = - 21.211631, 148.884849

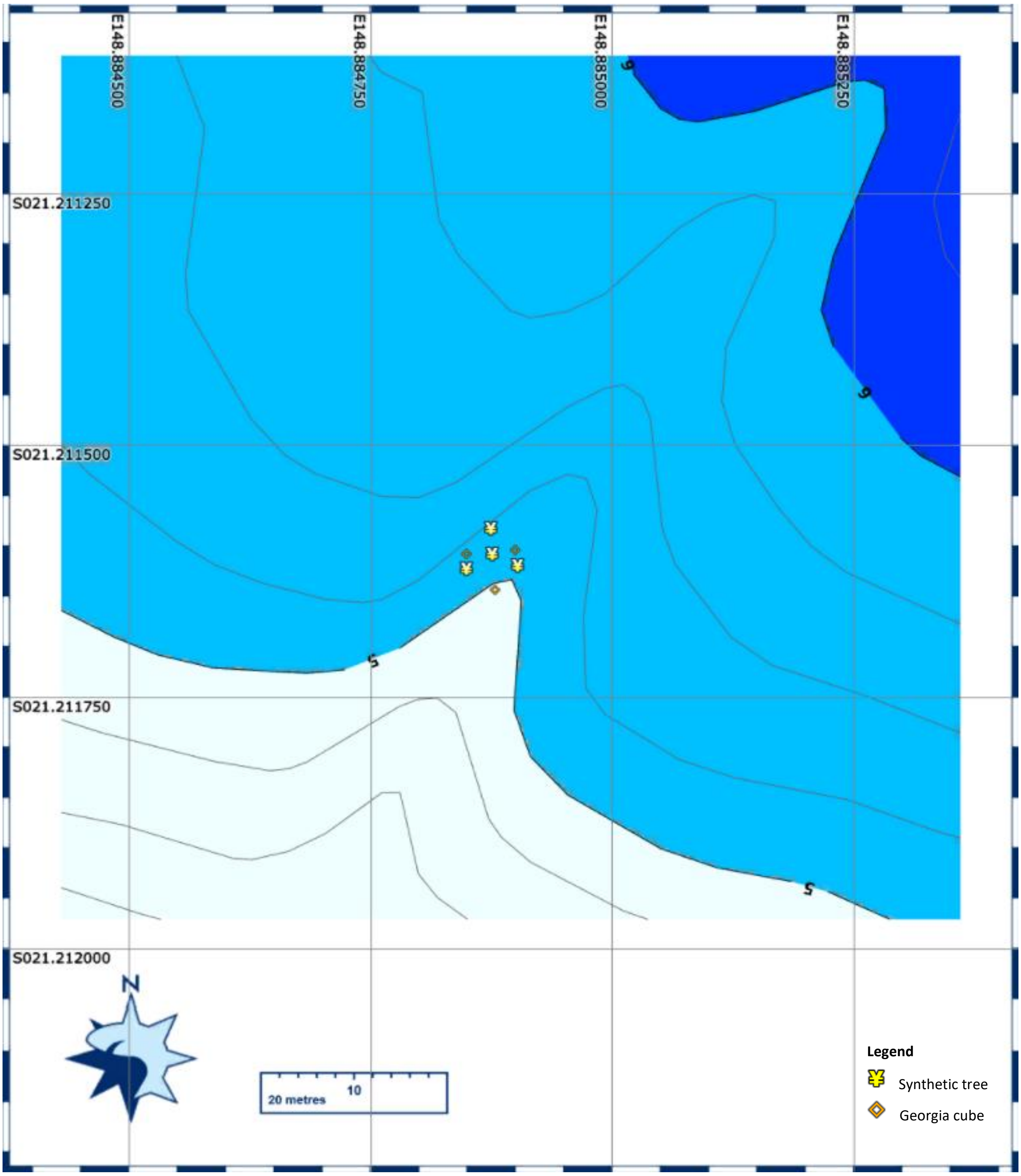


Figure 12. The location and deployment pattern of structures at FAS 15. Depth contours were generated at a dam supply level of 54.09 m AHD.

FAS 20 – line along a deeper hole

- Depth: 8.22 m at full supply level and 5.91 m at 90th percentile of water level
- In the middle of a hole in a channel with steep sides
- 1 x line of 3 synthetic trees with 2 brush piles at either end
- 3 m between each tree or pile
- Central coordinates = -21.204467, 148.874678

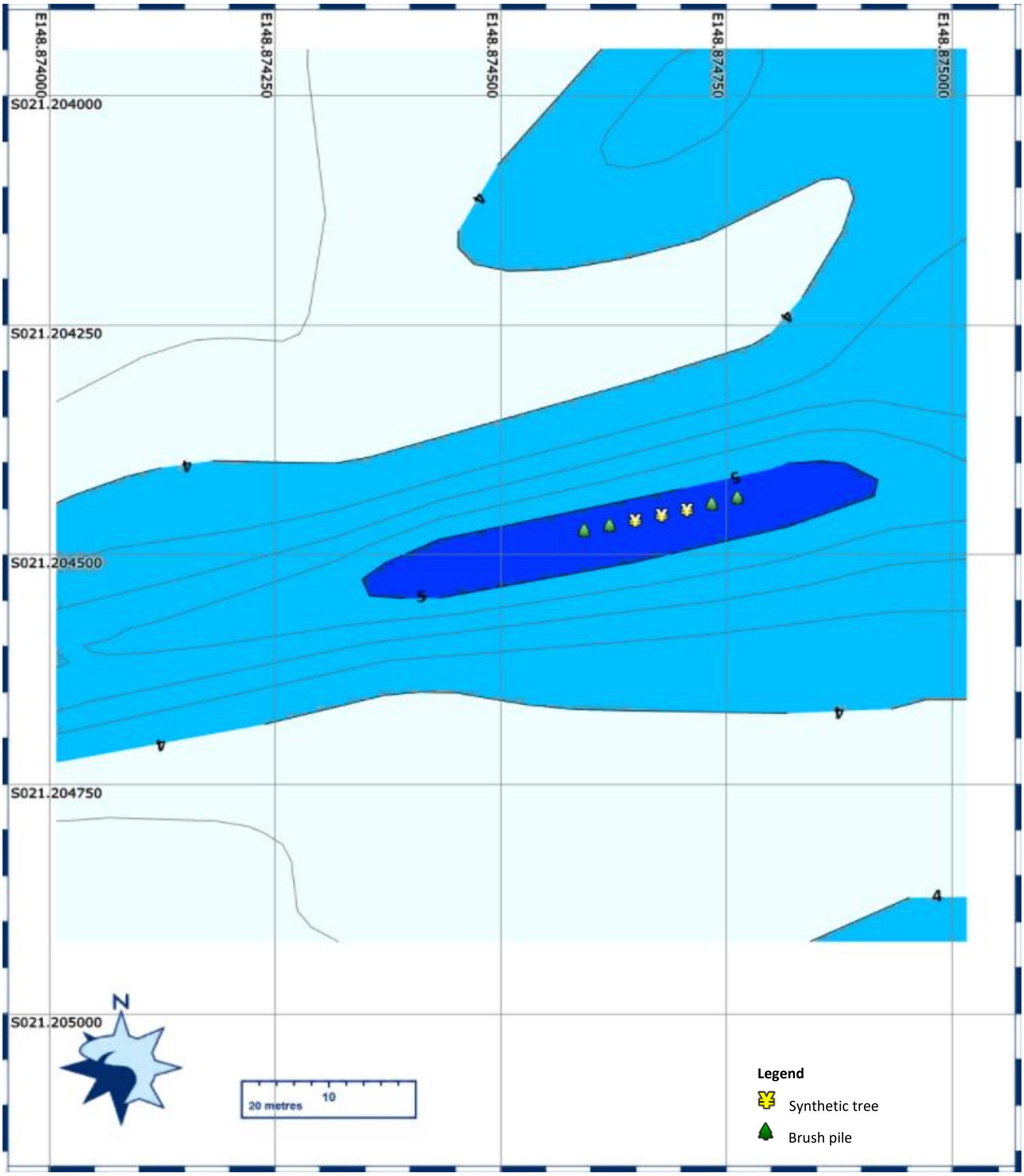


Figure 13. The location and deployment pattern of structures at FAS 20. Depth contours were generated at a dam supply level of 54.09 m AHD.

FAS 21 – on the flats near top of a drop off

- Depth: 7.02 m at full supply level and 4.71 m at 90th percentile of water level
- Along the top of a drop off into a channel
- 60 m away from any vegetation
- 1 x cross shaped cluster of 5 synthetic trees
- 3 m between each synthetic tree
- Central coordinates = -21.205877, 148.874436

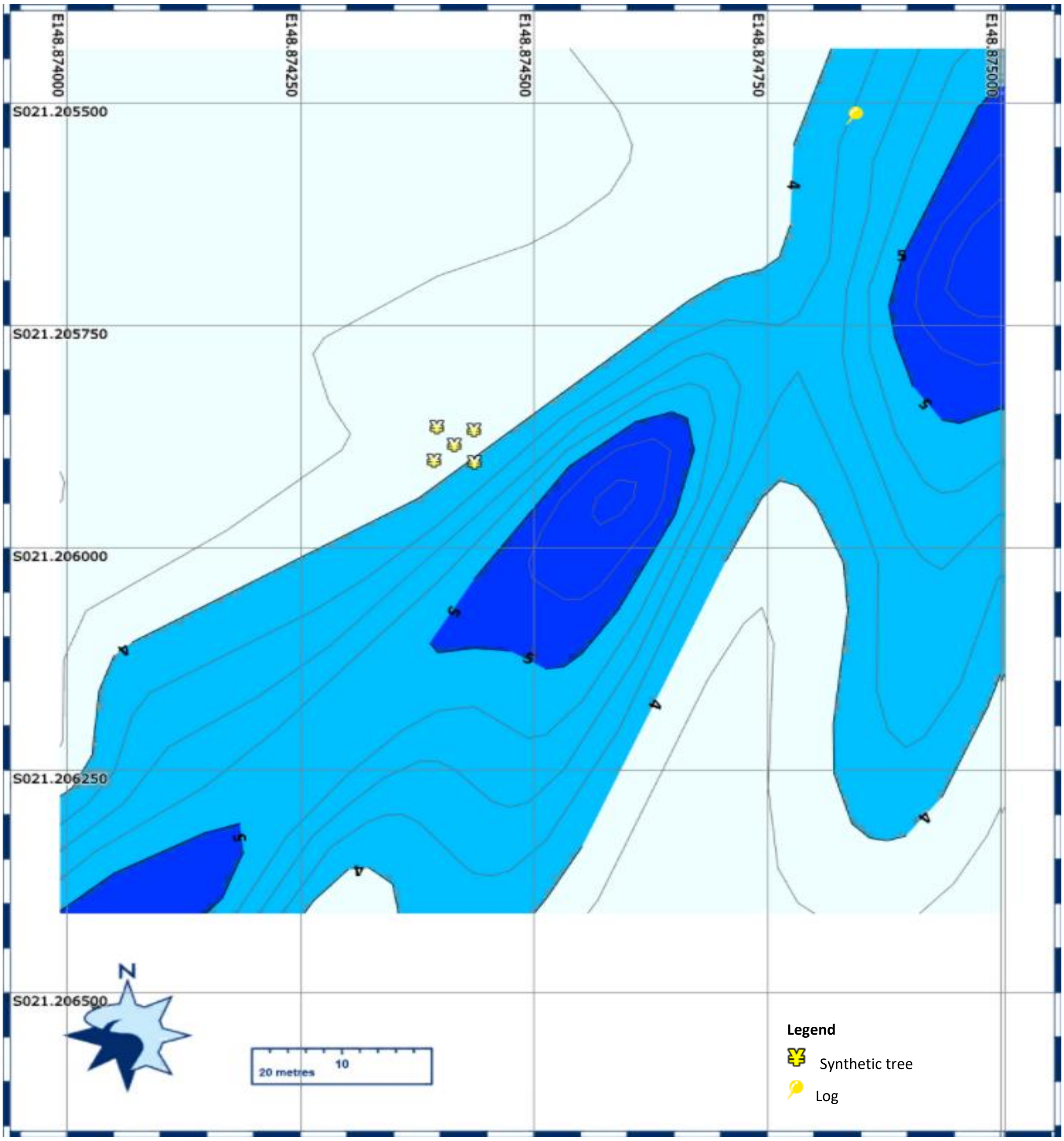


Figure 14. The location and deployment pattern of structures at FAS 21. Depth contours were generated at a dam supply level of 54.09 m AHD.

Appendix 4 – Plans for fish attractor designs

Synthetic tree

Materials:

1 x 2 m of 100 mm DWC for the trunk
23 x 2 m of 25 mm PVC pipe
1 x 200 mm piece of 25 mm conduit
1 x 20 L wide-based bucket or mould
15 L concrete

Tools:
Tape measure
Marker
Drill
33 mm hole saw
25 mm speed bore
De-burring tool

Methods:

1. Mark six straight lines lengthwise along the 100 mm PVC trunk at 60 degrees apart.
2. Make a small mark at 70 mm intervals along each line on the trunk from the top, finishing approx. 400 mm from the bottom.
3. Starting at the top, make a large mark at the 70 mm increment in every third row along two lines on opposite sides of the trunk.
4. Rotate the trunk to the next two lines opposite each other and repeat making large marks on the line at every third increment, but this time starting at the second increment from the top.
5. Repeat with the final two lines, starting at the third increment from the top. This should create a spiral pattern of large marks on the trunk.
6. Drill a 33 mm hole at each of the large marks. Do one side at a time, rather than trying to drill through both sides of the trunk in one go.
7. Also drill a 25 mm hole through both sides at the bottom of the trunk, 50 mm up from the end.
8. Insert a 200 mm piece of 25 mm conduit through these holes. This will help secure the trunk into the concrete base.
9. Stand the 100 mm PVC trunk vertically in the bucket with the end with the short piece of conduit down and add 15 L of concrete.
10. Brace the trunk vertically until the concrete has set.
11. Insert 2 m lengths of 25 mm PVC pipe into all the holes until they protrude equally on each side. Some holes may need to be de-burred to get the pipe through. Aim for a tight fit so the limbs will not fall out.

Georgia cube

Materials:

12 x 1.2 m lengths of 32 mm P12 PVC
8 x 32 mm 3-way side outlet elbows
16 x 1.4 m lengths slotted 100 mm diameter ag pipe
8 x 1.9 m lengths slotted 100 mm diameter ag pipe
4 x 0.2 m lengths slotted 100 mm diameter ag pipe
PVC primer
PVC glue
2 - 4 x concrete blocks
Silver nylon rope to attach the concrete blocks

Methods:

1. Create a 1.2 x 1.2 m base to the cube by gluing 4 lengths of the 32 mm PVC into 4 of the 3-way corners.
2. Create another identical square frame to act as the top of the cube.
3. Drill a 10 mm hole in the top of the 3-way corner of the top to let air escape.
4. Glue 4 x 1.2 m lengths vertically into the corners of the base to act as the uprights.
5. In the 1.4 m length of slotted ag pipe, drill 40-50 mm holes through each end approximately 5 cm in from the end.
6. Repeat with the 1.9 m lengths of slotted ag pipe.
7. Drill a hole through the middle of the 0.2 m length of slotted ag pipe.
8. Add a 0.2 m piece of ag pipe to each upright.
9. Follow by adding 2 x 1.4 m lengths across the frame in one direction.
10. Repeat with another 2 x 1.4 m lengths perpendicular to these.
11. Add 2 x 1.9 m lengths of ag pipe diagonally across the frame.
12. Repeat the process using the remaining 1.4 m and 1.9 m lengths.
13. Glue the top of the frame into place.
14. Tie the concrete weights to the corners.

Kinchant crib

Materials:

30 x 2 m lengths of 100 mm diameter PVC pipe
9 x 1.5 m lengths of galvanised M10 threaded rod
32 x galvanised M10 nuts
32 x galvanised M10 wide washers
4 x galvanised 10g x 25 screws
48 x 90 mm long pieces of 1 ¼" poly pipe

Tools:

Tape measure
Marker pen
Cordless drill
12.5-13.0 mm drill bit
Angle grinder with cutting disk
Spanners or sockets to fit M10 nuts
Knife to cut poly pipe

Methods:

1. In 28 of the 100 mm diameter PVC downpipe lengths, drill a 12.5 mm or 13 mm diameter hole at 100 mm and 1900 mm measured from the same end. Drill the holes through both sides of the pipe. Take care when drilling as the pipe can be brittle and may shatter if too much force is used. A cordless drill may be easier to use than a corded drill.
2. Add a nut and washer to one end of four 1.5 m lengths of threaded rod and insert the threaded rod through each end of two lengths of downpipe with the same hole patterns.
3. Lay the pipes on the ground and place 2 more lengths of downpipe of the opposite hole pattern perpendicular across the first 2. With the pipe centres 200 mm from the ends of layer 1. This will form the start of a cross hatch pattern.
4. Insert 4 more 1.5 m threaded rods through the top pipes and add washers and nuts to the lower end.
5. Add a third layer of two pipes of the original hole pattern, with the pipes parallel but the centres 120 mm offset towards the middle. This will cause the threaded rods to angle in towards each other in the shape of a pyramid.
6. Add the last two lengths of undrilled pipe in the middle of layer three, with pipe centres 150 mm each side of the centre mark. Drill a 13 mm whole in each pipe directly above where it crosses the row below and attached the two rows using the galvanised screws. These pipes will be used to support the mooring weights and help fill the void in the middle of the cube.

7. Keep adding alternate layers of downpipe until the crib is 14 layers tall.
8. Cut the 90 mm long lengths of 1 1/4” poly pipe lengthwise down 1 side with a knife or saw.
9. Insert a cut piece over each exposed bit of threaded rod between pipe layers to improve resistance to snagging by lures.
10. Ensure that the angles on each side are roughly equal and then add washers and nuts to the top of each threaded rod and tighten gently. Too much pressure may shatter the pipe.
11. Trim the top of any threaded rod protruding upwards past the nut with an angle grinder.
12. Cut the remaining threaded rod into 250 mm lengths with an angle grinder.
13. In each corner of the crib, where the top two rows intersect drill a 13 mm hole through both pipes.
14. Insert the threaded rod and tighten with washers and nuts. These short lengths will maintain the angle of the sides. Trim any rod protruding from the top with an angle grinder.
15. Repeat this process with each bottom corner. It may be easier to support the crib on bricks to gain access to the bottom nuts.
16. The cinder block weights are tied on just prior to deployment to make transport easier.

Suspended FAS

Materials:

3.0 m of 100 mm diameter PVC for trunk
34 x 3 m lengths of 25 mm PVC pressure pipe
2 x 100 mm PVC pipe caps
8 x 25 mm PVC pressure pipe end caps
5.5 m x 6 mm stainless wire plus spare depending on depth
3 stainless wire thimbles
1 stainless wire swivel
9 x stainless wire swages
3.3 m x 13 mm hose
0.7 m x 13 mm hose
2 x large stainless washers with 6 or 7 mm hole
2 x rubbing plates
3 x 35 kg+ concrete drop weights with tie points
0.8m x 10 mm galvanised chain
4 x stainless 10 mm D shackles
1 m x 1.0 mm stainless tie wire
1 large marker float (> 300 mm diameter)

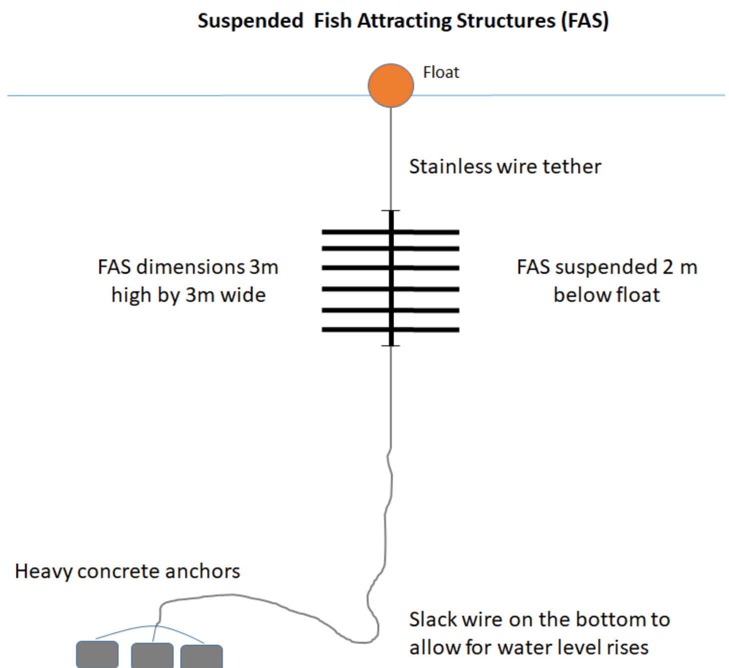
Tools:

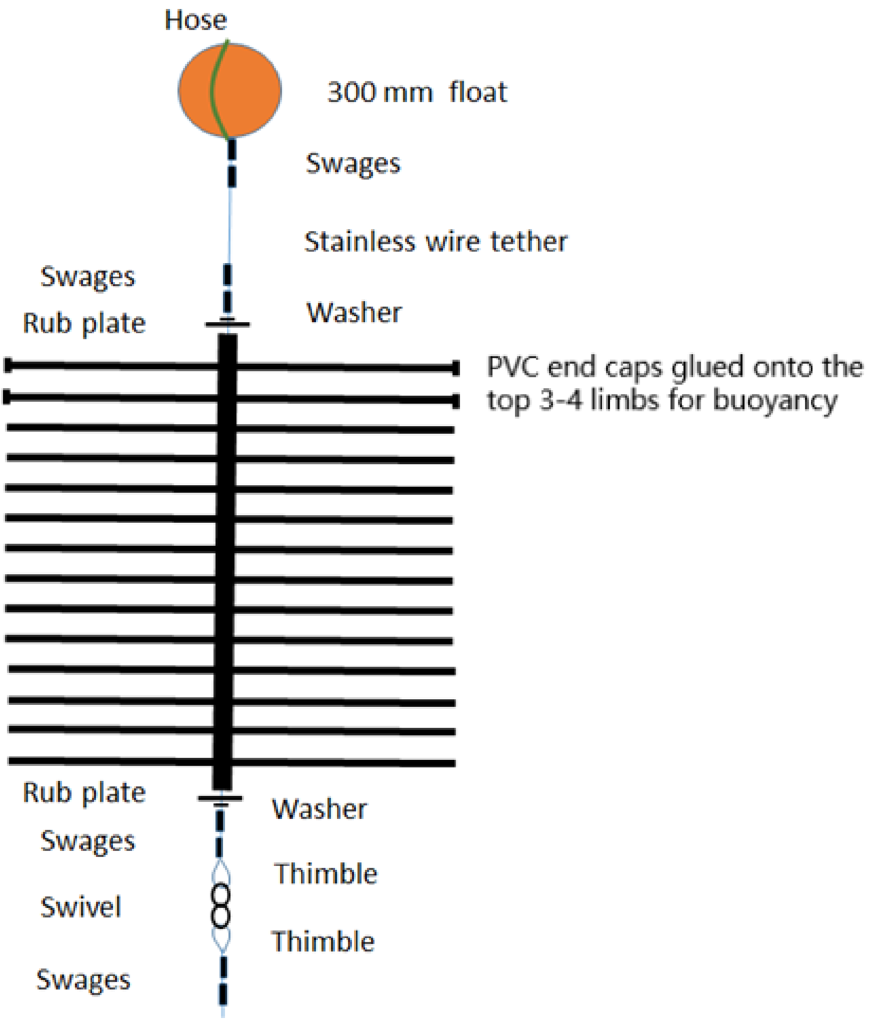
Tape measure
Marker pen
Drill
33 mm hole saw
Saw to cut PVC pipe
Deburring tool
Swaging tool
Pliers
Knife
PVC glue and primer

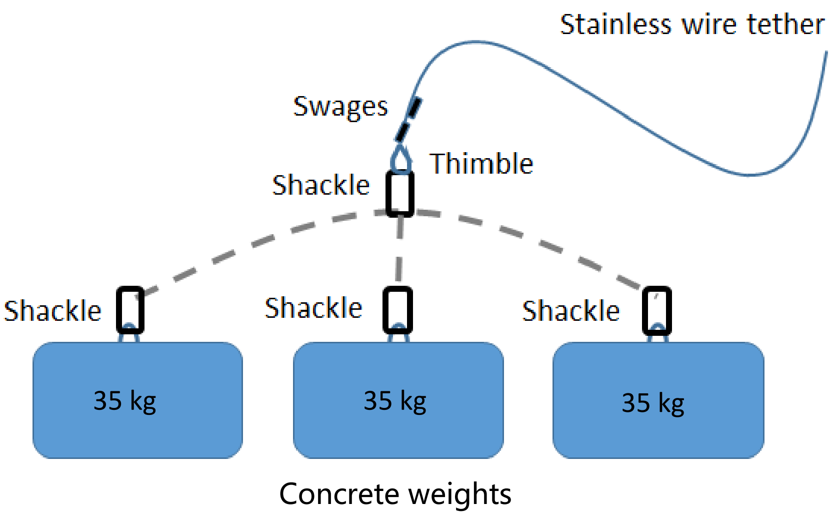
Methods:

1. Cut 34 x 3000 mm lengths of the 25 mm PVC pressure pipe for the branches.
2. Mark 34 rings at 70 mm intervals along the 100 mm trunk from the top, finishing approx. 120 mm from the bottom.
3. Divide each ring into 60º intervals.
4. Starting at opposite sides on the top ring, mark a pattern on the trunk so that each consecutive ring is marked at a 60º to the previous one. This will create two spiral patterns down the trunk.
5. Drill each a 33 mm hole at each of the points marked.
6. Deburr the holes with the deburring tool so the 25 mm PVC will pass through tightly.
7. Drill a 14 mm hole in each 100 mm PVC endcaps for the hose to pass through (ensure the hole is offset near the edge to make it easier for the hose to pass through).
8. Pass the long piece of hose through the hole in the end cap, through the 100mm PVC trunk and finally through the hole in the other end cap.
9. Drill to small holes in the trunk near the endcaps and cable tie the hose in place at either end.
10. Glue both end caps onto the 100 mm PVC trunk and trim the hose so that 20 mm protrudes the caps at either end.
11. Insert the 3 m lengths of 25 mm PVC into the holes until they protrude equally on each side.
12. Glue PVC end-caps onto the top 3 or 4 lengths of 25 mm PVC to create sealed sections for additional buoyancy.
13. Pass one end of the 6 mm stainless wire through 2 swages.
14. Continue to pass the wire through the 0.6 m piece of 13 mm hose.

15. Pass the wire and hose through the eye in the bottom of the float, situating the hose evenly on either side.
16. Pass the wire back through the swages, slide them up tight to the hose and crimp in place. The hose will help minimise chaffing on the float.
17. Drill a 7 mm hole in the 2 rubbing plates.
18. Thread a swage, followed by a washer and a rub plate onto the free end of the wire and slide up towards the float.
19. Thread the free end of the wire all the way through the hose in PVC trunk until it protrudes from the far end.
20. Add the second base plate, washer and 2 swages to the wire.
21. Pass the end of the wire through one end of the swivel, around a thimble and back through the swages.
22. Compress the swages into place keeping the tag end of the wire as short as possible. The second swage should sit right on the end of the wire tag as it sits against the washer.
23. Pull the wire upwards through the trunk until the lower rubbing plate sits flush to the bottom of the trunk.
24. Slide the top rubbing plate, washer and swage down to the top of the trunk and compress the swage in place.
25. Determine the depth where the suspended FAS is to be install and add 1.5 m to the depth at that location when at full water supply.
26. Cut the 6 mm wire to length, pass one end through 2 swages, over a thimble through the other eye of the swivel. Slide the swages up so the wire sits snug on the thimble and crimp into place.
27. Using 2 crimps and a thimble, create an eye in the other end of the wire.
28. Attach the 3 mooring weights together in a line by chain using shackles. Seize the shackle pins in place using the pieces of stainless tie wire.
29. Attach the eyelet in the bottom of the wire to the middle of the chain linking the three weights using a shackle and seize the shackle pin in place using the stainless tie-wire.
30. The suspended fish attractor is now ready for deployment. To aid moving the structure, the weights can be attached on the deployment vessel just prior to deployment.




Hose
300 mm float
Swages
Stainless wire tether
Swages
Rub plate
Washer
PVC end caps glued onto the top 3-4 limbs for buoyancy
Rub plate
Washer
Swages
Thimble
Swivel
Thimble
Swages


Stainless wire tether
Swages
Thimble
Shackle
Shackle
Shackle
Shackle
35 kg
35 kg
35 kg
Concrete weights